



The
Papua and New Guinea
Agricultural Journal

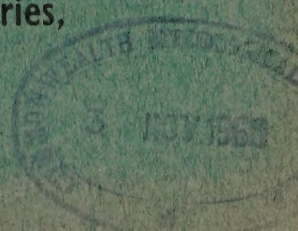
Vol. 13

June, 1960

No. 1



Department of Agriculture, Stock and Fisheries,
Port Moresby



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Former Issues of Gazette and Journal

The following numbers of the *Agricultural Gazette* have been issued :

New Guinea Agricultural Gazette—

- Volume 1, Number 1.
- Volume 2, Numbers 1, 2 and 3.
- Volume 3, Numbers 1 and 2.
- Volume 4, Numbers 1, 2, 3 and 4.
- Volume 5, Numbers 1, 2 and 3.
- Volume 6, Numbers 1, 2 and 3.
- Volume 7, Numbers 1, 2, 3 and 4.

The Papua and New Guinea Agricultural Gazette—

- Volume 8, Numbers 1, 2, 3 and 4.

The Papua and New Guinea Agricultural Journal—

- Volume 9, Numbers 1, 2, 3 and 4.
- Volume 10, Numbers 1, 2, 3 and 4.
- Volume 12, Numbers 1, 2, 3 and 4.

Copies of all numbers of the *Gazette* to Volume 7, No. 4, are out of print.



PLATE 1.—*Casuarinas and native gardens on steep Chimbu hillside.*

PATROL OF UPPER CHIMBU CENSUS DIVISION EASTERN HIGHLANDS

D. E. MONTGOMERY.

In September-October, 1957, Mr. D. Montgomery made a long patrol of the Upper Chimbu Census Division, in the Chimbu Subdistrict of the Eastern Highlands. The patrol was designed to compile a village agricultural census, but a number of observations as to apparent pressure of population on the land in the area were also made. These observations should be read in conjunction with an earlier Journal article "A Special Report on the Pagaku sub-clan" (Vol. 11 : 4) by J. W. Barrie. Since both these surveys were made, a more intensive investigation of the Chimbu area has begun. Mr. D. Montgomery, an Assistant Agricultural Officer when this paper was written, is at present Agricultural Officer at Bainyik, in the Sepik District.

THE object of the patrol was to collect data to compile an Agricultural Village Census and, from this, together with general observations, to make a reconnaissance of the extent of land population pressure. This pressure was recognized as a future problem in the area shortly after the Chimbu Census Division came under Government control. Later, following Government and mission influence, and the introduction of health services and improved subsistence crops, the ratio of births over deaths began to rise.

On the patrol, the writer accompanied two Native Affairs officers, who were conducting an annual census. Other members of the patrol were two agricultural field workers, four native agricultural trainees, five members of the Royal Papuan and New Guinea Constabulary, one interpreter and one native medical orderly.

As the patrol took place during the annual census check, the villagers in the area gathered to await the patrol. Many treated it as an occasion for celebration.

The agricultural census was made using a question and answer technique, using an interpreter where necessary. Later, the writer, accompanied by agricultural fieldworkers, trainees and village members, inspected crop gardens and held discussions on economic crops and other matters pertaining to agriculture and land use.

GEOGRAPHY AND RELIEF

The Upper Chimbu Census Division has a land area of approximately 190 square miles and forms part of the Chimbu Subdistrict. The Subdistrict Headquarters are centrally located at Kundiawa. The census division comprises a series of high ridges and young river valleys,

which form the watershed of the fast-flowing Chimbu River and is bounded on three sides by steep mountain ranges. In the north is the Bismarck Range, the main feature of which is rugged Mt. Wilhelm, 15,400 ft., the highest mountain in the Territory of Papua and New Guinea. On the western side is the Kerowagi Range, with the Goroka/Asaro divide forming the Eastern boundary.

Most of the populated areas lie between 4,600 ft. and 7,800 ft., which is the limit of subsistence agriculture. Cultivation extends over the steep ridge slopes, which are a feature of the area.

The route followed by the patrol necessitated steep and frequent climbs, sometimes as much as 3,000 ft. a day from one village to the next. The separate village groups are situated in different valleys of the watershed and crossing from one valley to another may often mean climbs and descents of several thousand feet.

However, when walking in a particular valley, it is usual to keep to the native roads, which to some degree follow the contour. But when the main (Chimbu River) valley is crossed this also involves a steep climb. Leaving a village at about 5,500 ft a decent is made to the river at 4,000 ft. and then a climb on the other side to the next village, or gardens, at about 6,000 ft. Slopes sometimes exceed 50 per cent.

A villager, moving from his house to his more distant gardens in the morning, may have to climb 500 to 1,000 ft. to reach his garden area.

In the upper reaches of the Chimbu Valley, slopes are more gentle from approximately 8,500 ft. to about 10,000 ft., but prevailing temperatures at this altitude are too cold and subsistence crops make little growth.

Soils

The main soil type is a heavy clay or clay-loam of reasonable fertility but little depth which has been developed on limestone. There are no areas of alluvial soil.

Climate

There are two main seasons, the north-west or wet season which extends from November to April and the dry season when rainfall is limited, for the rest of the year. The average annual rainfall over the past four years has been 85.8 inches.

During the north-west season, heavy build-up of clouds in the morning and rain in the early afternoon greatly reduces the hours of sunlight.

Winds in all seasons tend to be light.

Ecology

Little natural timber is found in the areas which are cultivated and the spread of subsistence gardens is, in fact, forcing the timber line slowly to recede. Above 7,500 ft. dense stands of rain forest containing many timber species exist. Above 11,000 feet little growth takes place and tussocky scrub and hardy grasses predominate. Mt. Wilhelm, which was climbed by the writer during the course of the patrol, is completely devoid of any vegetative growth, apart from mosses, above 14,000 feet.

In the cultivated areas, the people make extensive use of *Casuarinas* as part of the rotational system of subsistence gardening. Some small secondary regrowth timbers are also found among the *casuarinas*, but these have no specific use. Areas which are gardened and which do not have *Casuarinas* growing generally support a mixture of two grasses, *Imperata* spp. and *Themeda* spp. The former predominates.

PEOPLE

Before the area came under Administration influence, the Chimbus were apparently a hardy, war-like race, regularly involved in raiding parties on their neighbours. However the people have accepted Government influence and are now peaceful and law-abiding.

The basic social pattern appears to have changed little, but the people are slowly becoming more conscious of Government services available to assist them. The day-to-day existence remains unchanged, with women doing the essential chores of cooking and gardening, while the men carry out the heavier work of post splitting, fence construction and house building.

Linguistic groups

There is no division by different languages. Chimbu is spoken and understood throughout the area.

State of health

The diet of the adult population appears adequate, providing the available foodstuffs are correctly utilized, but much needs to be done to assist infants. The nutritional disease *kwashiorkor* exists among children because of an inade-

quate diet. This follows social "tambus" which prevent children taking part in feasts and celebrations until they reach maturity, with the result that they get little of the higher protein foods which predominate at these celebrations. The problem of child malnutrition would probably disappear if parents could be persuaded to prepare foods for their children from pigs, fowls, eggs and fresh vegetables, rather than keeping them on a diet of sweet potato or corn.

Malaria does occur, generally among returned labourers who have made contact with the disease during a contract period in coastal employment. Tuberculosis and goitre are also present.

Diet

On the whole, the diet of the adults is excellent with more than 60 different subsistence crops, together with protein supplements in the form of pig and fowl meats, always available, but these are rarely utilized. Periods of food shortage do occur during some dry seasons, but earlier investigations of these food shortages indicated that they usually follow a period of feasting and celebration. In these times, gardens are neglected and a period of hunger results.

Land tenure and customs

Land tenure follows the patrilineal system and very few serious disputes arise over land owner-

ship. The Chimbuses are also very jealous of land rights and land plays an important part in their basic human relationships.

Education level and outlook

Very few people of this area have received or are receiving any formal education. There are no Government schools and the Mission schools teach a language which is closer to Pidgin than to English.

On the whole, the way of life is still primitive, the most important advances being made in the field of agriculture, health and general administration.

Living Standards

Living standards can only be described as poor and the writer feels that the improvement of the living standard in this area will come only when population/land pressures are overcome and a cash income is provided.

Houses are small and squat, with low timber walls and a low pitched roof, formed by a framework of young saplings and split casuarinas. Tightly thatched kunai or other grasses are used to roof this structure. The emphasis is on warmth and ventilation is almost non-existent.

The only aperture is a small door which requires one to bend double when entering the house.

PLATE 2.—Chimbu men in ceremonial dress with pigs, fowls and vegetables for patrol.



Pigs still share the same houses as the family, mainly because they provide warmth and as pigs are a treasured item in the social pattern, every care is taken of the animals.

CROPS

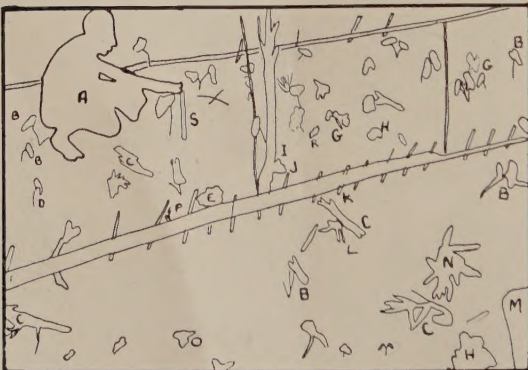
Subsistence

Agriculture is the life of these people and the evolved system of subsistence agriculture suits

the available land area and the steep slopes of the country. Social customs, festivities and in fact all celebrations are centred around food and feasting. Certain gardens are prepared at certain times to ensure an abundance of food for an annual occasion ; marriages are celebrated with the slaughtering of pigs ; special preparation of vegetable foods takes place ; the onset



PLATE 3 and 3A.—Section of native garden. Key is :



- A—Fieldworker Buasi Kepu.
- B—Taro.
- C—Sugar cane.
- D—"Tankard" (croton).
- E—Cluster of bean plants.
- F—Casuarina trunk.
- G—Yams.
- H—Beans.
- I—Banana sucker.
- J—Potato.
- K—Retaining stick.
- L—Ginger.
- M—Edible pit-pit.
- N—Corn variety.
- O—Edible waxy leaf.
- P—Corn variety.
- R—Cucumber.
- S—Foot ruler.

of the first rains warrants a "Sing-sing", together with the consumption of quantities of food of many kinds; and a feast follows the clearing and preparation of a new garden. Thus the pattern of subsistence agriculture is clearly defined to meet the requirements of these festivities, apart from normal day-to-day food.

The most important and the most intensively cultivated crop is the sweet potato and the people have at least six named varieties for planting at different times, in different locations and for different social and ceremonial functions.

This crop is the basis of their intense rotational system and may be grown on the same area for up to three years with various other subsistence crops, which form part of the defined rotational pattern. The sweet potato plantings are generally confined to the heavier and moister clay soils of the slopes with the other annual crops, sugar cane, pit pit, yams, taros, native and European type vegetables being planted in the more fertile depressions at the base of the slopes.

Where the available land is limited, in the case of smaller landholders or where a small fertile area exists, a mixture of up to 20 annual and bi-annual crops may be planted in an area sometimes no more than 400 square feet, with sweet potato planted on an even smaller area on the garden perimeter. Judging by the intensive system of cultivation adopted by these people, it would appear probable that there is very little ground below the 7,500 ft. contour which has not been cultivated at some stage.

No defined planting season could be determined by the writer. Garden preparation and planting appeared to be a continual cycle and the main activity of the year. As Barrie (1958) states:

"There does, however, appear to be a general slackening off in planting of sweet potato gardens shortly after the commencement of the wet season—usually in November."

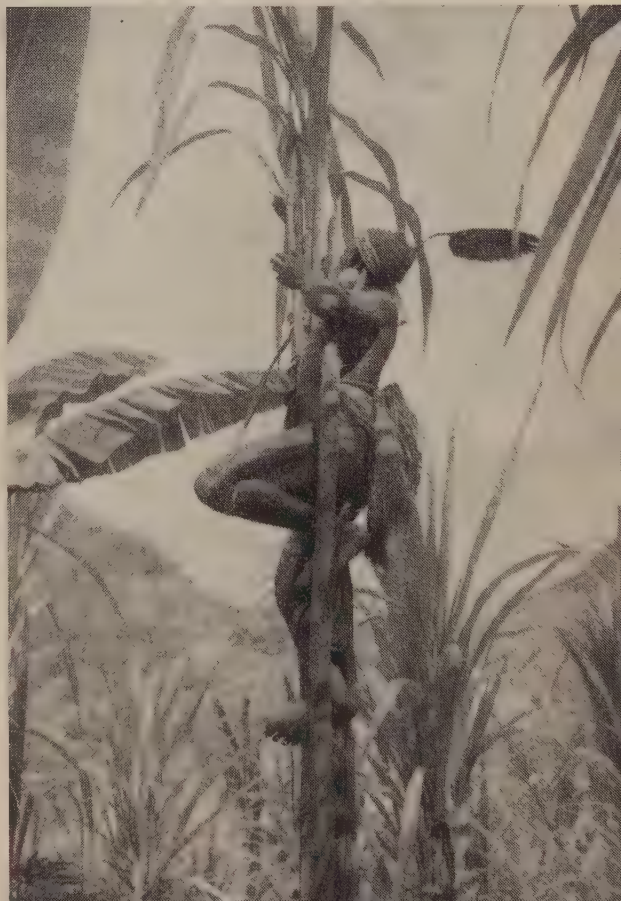
The reason for this would appear to be the risk of erosion at the onset of the heavy rains of the north-west season as this would be greatest at this time. The people appear to be conscious of the dangers of erosion on steep slopes because even on the lesser slopes and in the drier months, the gardens which have just

been prepared and cultivated are protected from the elements by a covering of dead branches and the foliage of the *Casuarina*, cut from the dead and dying trees, which formed part of the previous rotational cycle. This covering is burned and the garden "broomed" just before the planting of the subsistence crop.

The *Casuarina* tree plays an important part in the rotational system of the Chimbu gardener. Where an area can support continued cropping of sweet potato and other annuals for periods of up to three years, the *Casuarina* seedlings are planted in the second and third years of the cycle. After the last crop has been harvested, the ground is allowed to revert to the predominating grass species of the area and the *Casuarinas* quickly become established, making rapid growth in the first few years. When a short rotation period is expected, the *Casuarinas* are planted with the subsistence crops in the first year.

The ground may remain under *Casuarina* fallow for as long as 20 years or as little as six

PLATE 4.—*Sugar cane.*



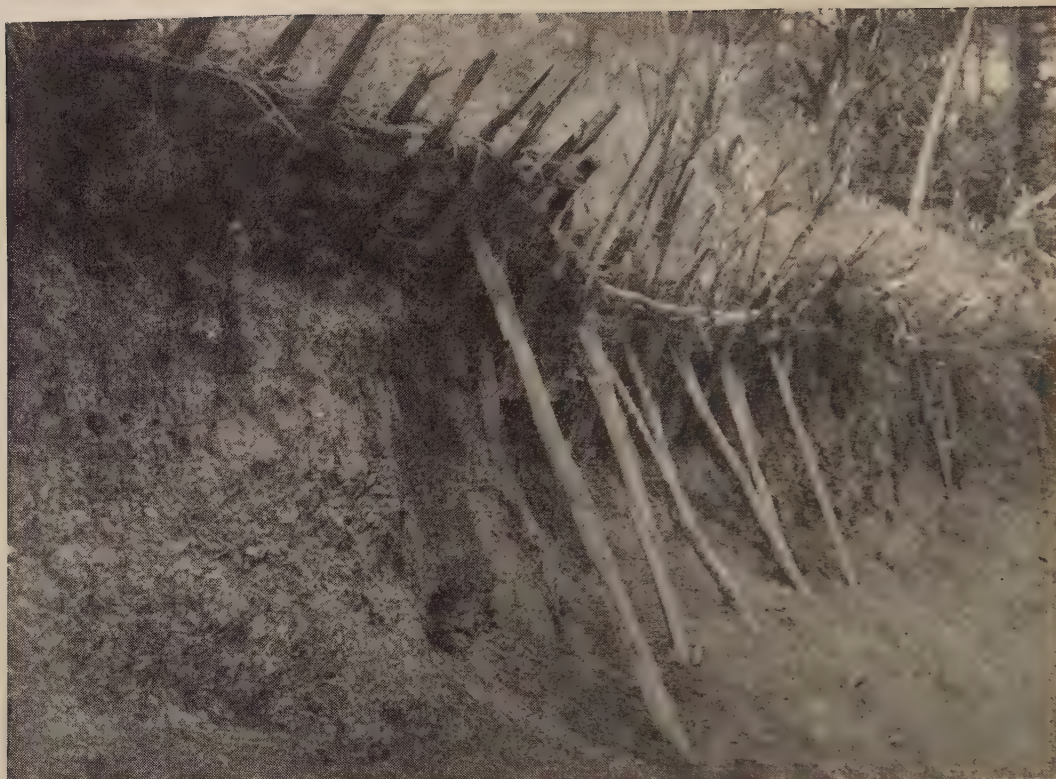


PLATE 5.—*Retaining Terrace.*

years, depending on the amount of ground available to the landholder and the location and fertility of that ground.

Where terracing is used, the system serves a twofold purpose. Its main function is to prevent soil loss by sheet erosion, but the terraces are so constructed that the water run-off during heavy rain is only checked and continues to move more slowly down the slope, increasing water absorption of the soil and leaving a small build-up of topsoil at each terrace. If a solid terrace were constructed and no provision was made to allow for slow dispersal of the water, the consequent damage by large quantities of water building up during a downpour could be disastrous.

Split timber planks and the branches of *Casuarinas* are the usual materials used in the construction of these terraces. However, occasionally large stones or live hedges are employed. The height of the terraces and the parallel distances apart depends on the steepness of the

slope. Pegs are first driven into the ground, these being made from the stouter branches of the *Casuarina* and the split lengths of the tree are laid against these pegs on the uphill side of the slope. The split lengths are then firmly fixed in place by driving a further peg against them. Above the plank or planks, small branches and twigs are placed and pegged with small sticks driven vertically into the ground. From a distance, these terraces, constructed on newly cultivated ground, give an appearance of contour ploughing or drainage ditches and in a sense they serve the same purpose.

On those areas which do not lend themselves to rejuvenation by *Casuarinas*, generally shallow, infertile, steep and exposed limestone slopes and ridges, local grasses predominate and a small area may be "cultivated" at irregular intervals and planted to sweet potatoes. The resultant crop may be used to feed a few pigs.

The difficulties created by the steepness of the country cannot be over-emphasized and the

system of land use adopted by these people has been evolved by them to overcome problems associated with the slopes. It appears that little can be done to improve the existing system. In other areas of Papua and New Guinea, country similar to that which is found in the Upper Chimbu Census Division would in all probability remain unused, except for timber requirements and the occasional bush garden. However, in the Upper Chimbu the pressure of population is forcing gardens up the slopes and driving back the timber line.

Domestic animals

Pigs, apart from a mixture of dogs, are the only domestic animals of importance found in the area, and they play an important part in the lives of the people. All pigs found in the area are wholly or partly domesticated and show strong indications of improved breeding by European strains, particularly Berkshires.

The degree of domestication depends on the part the pigs will play in future pig-killing ceremonies. They still play an important role in bride price and wealth is dictated to a certain extent by the number of pigs an individual owns.

In a litter, one or two of the best suckers are selected and the rest are allowed to roam at will in the village and through the surrounding country. The owners make a careful note of their pigs' distinguishing marks, and in some places a system of ear marks is used when pigs show identical characteristics.

The one or two pigs selected from the litter are carefully nursed and fed, being confined to the village area and the female houses at all times. These pigs are reared for use at particular ceremonial occasions, which may be planned for up to six years in advance. The women show much affection and attention towards these pigs

PLATE 6.—*Influence of imported breeds can be seen in these pigs.*

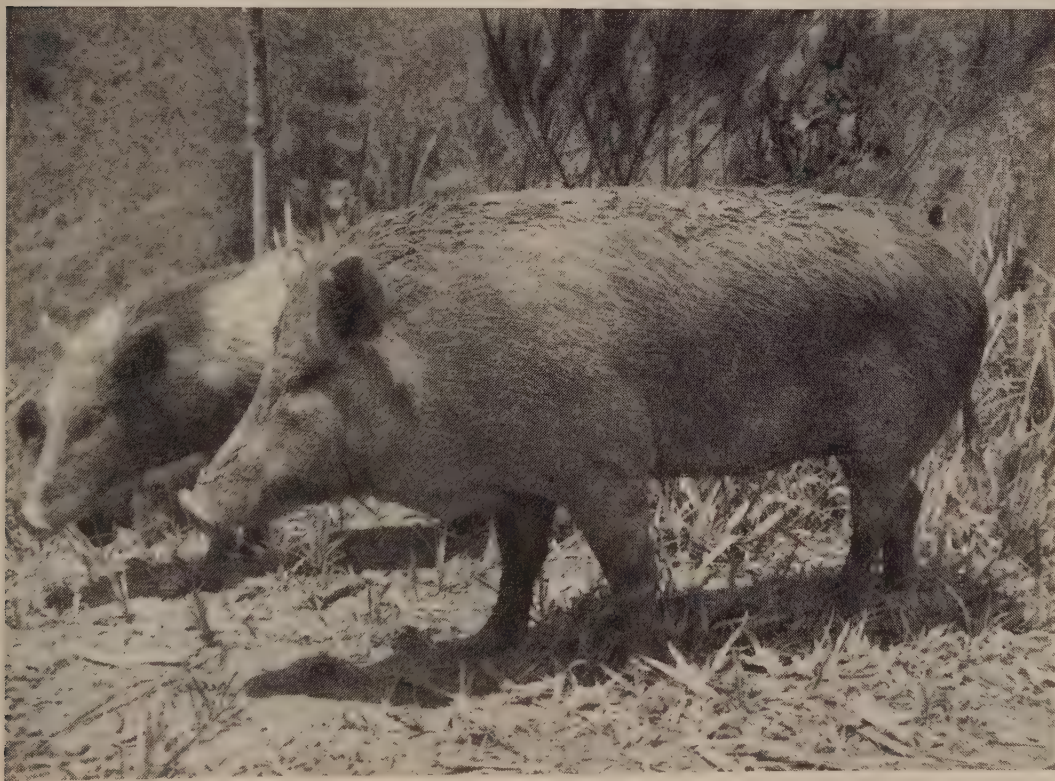




PLATE 7.—*Tobacco leaf.*

and, as has been mentioned, the animals share the warmth of the houses with the women and children.

Male pigs are usually castrated early in life. After weaning the pigs are leg-roped and may accompany the women to the garden sites. As a result their diet is appreciably better than those pigs which receive no special attentions or privileges.

Most pig killings take place at regular intervals and at the time of the patrol a census taken showed a pig population of 24,000 animals of all ages. No major killings had taken place for at least three years and the next big pig-killing ceremony was being planned for 1959. A few pigs are killed regularly, to celebrate marriages, births, sexual maturity, the completion of a new garden, the return of members of a family from a period of indentured labour and on the occasion of a Government patrol.

Cash crops

The people are aware of the advantages of economic crops. Before the introduction of coffee (*C. arabica*) to the Chimbu area, a small cash income was obtained from the sale of fresh foods, mainly sweet potatoes, cabbages, sugar cane and tomatoes to the Government station at Kundiawa and to mission bodies in the area.

Most of the money entering the area comes from the earnings of returned labourers—not only the contract labour which works on the coast, but also the casual labour which is found scattered through the Highlands.

POPULATION RISE AND PRESSURES

The population figures for the Upper Chimbu Census Division (below) show the phenomenal rate of population increase for this area.



PLATE 8.—*Peas are sold as a vegetable where markets can be reached.*

On the basis of these figures, a conservative estimate of population at the end of ten years is a total of 24,000. As the population per square mile of arable land now exceeds 260 (remembering that only about 80 square miles of land appears to be suitable for agriculture) the arable land appears to be inadequate. When the term "arable land" is used, it covers land descriptions much broader than the conventional definition. In the Chimbu, arable land is any which is capable of supporting vegetation. Slopes of more than 60 per cent. are being cultivated in this area.

There appears little which can be done to assist these people with commercial crops. The coffee census figures for the area show a total of only $11\frac{1}{2}$ acres of coffee for 19,000 people, or approximately a third of a tree per individual.

These figures lead to the following conclusions :—

1. The Upper Chimbu Valley will be unlikely to develop a cash crop in the form of coffee, which utilises existing land areas.
2. Subsistence agriculture should not, under any circumstances be allowed to make way for a cash crop, because this would interfere with food needs of the people.

3. Accordingly, the economic potential of the Upper Chimbu Valley is poor.

The people in the area do realize the advantages of growing cash crops, but it is the duty of the Administration to see that agricultural development, which may result in detriment to the welfare of these people, is not allowed to take place.

A possible answer to the problem of over population lies in resettlement, but this again presents problems which would appear insurmountable at the present stage of educational advancement of these people. In discussions, the local people have indicated that they do not want to leave their land. This is understandable when the problems of social adjustment involved are considered. If any resettlement programme took place, it would involve a complete social and technological change, assuming that the people would be resettled on an area sufficient to provide for the food requirements of a family unit, together with the opportunity of taking part in a scheme for economic development.

The alternative to resettlement is that of outside employment. Chimbuses provide an appreciable proportion of the Territory's labour force. The question of technical education is raised as a means of improving the standard of labour they have to offer.

STIMULATION OF THE YIELD OF RUBBER TREES AS A ROUTINE ESTATE PRACTICE

Field experiments on the use of synthetic growth substances to stimulate yields have been in progress since 1951 at the Rubber Research Institute of Malaya. This article, reprinted from Planters' Bulletin No. 45 by courtesy of the Rubber Research Institute recommends usages of these substances in routine estate practice. Properties of available stimulants, methods of application and yield response are discussed. Finally a schedule is suggested for tapping and stimulation of buddings and seedlings grown under normal management. Research on stimulants is also being undertaken by the Department of Agriculture, Stock and Fisheries, but this is necessarily a long-term project and it will be some time before firm recommendations can be made as a result of local experience.

Properties of Available Stimulants

There are at present four proprietary yield stimulants available in Malaya :

Trade name	Active ingredients
1. Flomore	2,4,5-T
2. Star Brand	2,4,5-T
3. Stimulex	2,4-D
4. Ready Rub	2,4,5-T

Flomore and Star Brand stimulants are formulations of similar composition, containing 1 per cent. 2,4,5-T, and prepared according to R.R.I. recommendations. They have a greasy appearance and are for application to scraped bark below the tapping cut. They are unsuitable for monthly or bi-monthly application above the cut, if users attach any importance to the quality of the renewing bark for future tapping.

Stimulex is a fluid formulation containing 2,4-D in a mixture of vegetable oils. Its stimulating effect is of the same order as that of the 2,4,5-T formulations but it is less injurious to the bark tissue. Stimulex may be applied to tapped bark above the cut at monthly or bi-monthly intervals, but overlapping of the areas of bark treated with stimulant must be avoided.

Like the 2,4,5-T stimulants, Stimulex has to be applied to scraped bark if applied below a downward cut. This stimulant needs stirring before use.

Ready Rub contains 2,4,5-T. It is intended to be applied to unscraped bark below the tapping cut and should not be applied to renewing bark above the cut.

Results at present available suggest that Ready Rub is less effective than any of the other stimulants on renewed bark ; satisfactory results have been recorded from application to virgin bark during ladder tapping. Ready Rub should be stirred before use.

Method of Application of Yield Stimulant

On Lightly Scraped Bark below the Tapping Cut

The depth of scraping of virgin bark can be determined by removing first the dead cork, then a thin greenish layer and finally a smooth yellowish layer. This is the correct depth of scraping and is confirmed by the presence of coarse reddish tissue, and in many cases by the appearance of minute drops of latex. On no account should latex ooze out after scraping.

Scraping of renewed bark should not go deeper than the typical reddish layer ; it can be done with a stiff steel wire brush which is flexible and does not cause serious wounding. Any hard steel scraper is suitable for use on virgin or thick renewed bark.

The small latex drops (and, if there has been any accidental wounding, the outflowing latex) should be given time to dry before the stimulant is applied ; intermingling of the latex with the stimulant should be avoided as this leads to a

thick application resulting in swelling, burring and cracking of the treated bark, which may dry up and rot away to the cambium. We therefore recommend scraping in the morning and application of the stimulant in the afternoon or, if rain or other circumstances interfere, the next morning.

If an excessive amount of dried latex covers the bark after scraping this should be removed before the stimulant is applied; but it is better to leave the few beads of latex from properly scraped trees untouched, as removal may cause renewed exudation of latex.

The greasy 2,4,5-T yield stimulants can be conveniently applied with a flat $1\frac{1}{2}$ -inch paint brush, provided instructions previously noted have been adhered to, difficulty in application is generally caused by mixing of latex and stimulant. On no account should the compound be heated. Stimulex is, by its fluid nature, easier to apply than the greasy preparations, but like these should not mix with latex. Care should be taken that it does not run down to unscraped bark beneath the strip where it has been applied.

The treated strip of bark must be tapped away within three months after application. The stimulant should therefore be applied to a strip not more than $2\frac{1}{2}$ inches deep on alternate-daily or 2 inches on third-daily tapping of a half-circumference cut. Application should be made thinly and evenly; this can be ensured by allowing one man to rub the painted bark strips with a rag so that any excess stimulant is removed.

One man can scrape either 125 average-sized rubber trees tapped on a low half-circumference cut, or 75 trees tapped on ladder cuts, per day. For painting, a fair task might be 350 trees with low cuts or 250 trees with ladder tapping. Similar tasks can be given to the man who removes the excess stimulant from the painted strips. These figures are meant as a guide only and much depends on the girth of the trees, the height of the cuts and the type of ladder used; these factors also determine the number of trees which can be treated with a gallon of stimulant. 500 average-sized trees can be treated with one gallon if applications are made below one half-circumference cut per tree.

The total cost of treatment per tree tapped on one half-circumference cut, including labour and material, is between 4 and 8 cents, depending on the size of the trees, the position of the cuts and the type of stimulant used.

On Renewing Bark above the Tapping Cut

We recommend that of the available yield stimulants only Stimulex should be used for this method of application, in which the stimulant is applied at monthly or bi-monthly intervals to the thin film of bark left after the preceding month or two months of tapping. An artist's half-inch paint brush is most suitable for this purpose. Application should be made on a non-tapping day and the scrap should not be removed before application, as this would result in mixing of latex and stimulant.

On Unscraped Bark below the Tapping Cut

Of the available yield stimulants, only Ready Rub gives an increase in yield level if applied to unscraped bark below the tapping cut. When tapping alternate daily, not more than $2\frac{1}{2}$ inches of bark below the half-circumference cut should be treated. Care must be taken that the stimulant, which on a hot day can be a rather thin fluid, does not run down the bark.

Age at which Rubber Trees may be Stimulated

Normally a rubber tree is brought into tapping between 5 and 7 years after planting or budding. Before the trees are opened for tapping they have a yearly girth increment of some 3 to 4 inches per year. When the trees are opened for tapping, the rate of girth increment is slowed down markedly; several of the modern high yielding clones in particular show very poor girthing on tapping.

It has been shown in an experiment carried out on Prang Besar Further Proof seedlings that application of a yield stimulant to young trees checks growth even more severely. Owing to late dripping, the small extra yield obtained by stimulating such young trees is collected mainly as cup-lumps if no second collection is made. A similar disappointing response to stimulation has been recorded in other experiments on young budded trees, and it appears that young trees should not be stimulated.

Very satisfactory results have been obtained when 18-year-old buddings and seedlings have been treated with a yield stimulant. At this age rubber trees have normally reached or already passed their peak performance, and there is no further build-up in yield level. The rate of growth in terms of girth has levelled off to a small yearly increment. Such trees can be treated with a stimulant, and despite high increases in yield the growth rate is not appreciably retarded. This has been confirmed in several experiments, one of which has been in progress since February 1952. The use of a stimulant may thus be considered at approximately the eighteenth year of life, when the virgin bark of the low panels of the trees has been tapped away. This does not mean that we recommend this treatment as ordinary estate routine, but if for some reason a temporary increased output is required from the mature areas, such trees may be stimulated without risk to their future performance.

Quality of Renewed Bark after Half-Yearly Stimulation below the Cut

One of our experiments has now reached the stage where we can express an opinion on the quality of bark which has been stimulated in the past. We are at present tapping second renewal bark of clonal seedlings which were stimulated when tapped on first renewal bark. Half-yearly application of a yield stimulant to a 3-inch strip of scraped bark below the cut has been continued throughout. The tapping system is S/2.d/2.100 per cent. The second renewal bark of stimulated trees is 1-1½ mm thicker than the bark of the unstimulated control trees. The yield appeared to be quite normal and a good response was obtained to subsequent application of a stimulant which, however, resulted in severe damage to the bark of third renewal—a phenomenon generally observed when thin second renewal bark is stimulated.

These observations have given us more confidence in the use of stimulants, as we now have reliable evidence that a normal yield is obtainable from bark which has renewed after stimulation below the cut at the first renewal stage. The standard of tapping should of course be high, since stimulants aggravate tapping wounds.

Quality of Renewed Bark after Monthly or Bi-monthly Stimulation above the Cut

We have already stated that only Stimulex (a 2,4-D formulation) should be considered for this method, which is at least as effective as the ordinary method of half-yearly application below the cut when thin renewed bark is being tapped. (However, in virgin bark at high level, or on thick first-renewal bark, the half-yearly application below the cut gives a better yield response.) The thickness of the bark treated above the cut is markedly increased by formation of non-latex-bearing tissue in the cork region. If overlapping of the stimulated strips is avoided, the bark may renew quite smoothly without the burring and cracking which occurs when a 2,4,5-T formulation is applied above the cut.

In bark which is smoothly renewed in this way, the latex vessel system is normal and the records of tapping show that the yield capacity is similar to that of untreated control trees. Shallow tapping of this thick renewed bark should not be permitted, as the extra thickness does not contain latex vessels.

Response to Successive Applications of Stimulant

There is a decreasing response to successive applications of a stimulant, which may be largely explained by the position of the tapping cut. If, on clonal seedlings, the tapping cut is low down the stem, the response to stimulation is small regardless of whether the application is the first or has been preceded by earlier applications on the same panel; in the latter case, however, the response is more disappointing and may even be negative (see *Figures 1 and 2*).

A factor contributing to this is that the bark at the lower part of the stem of a seedling tree is usually of second renewal when the tree has reached the age when stimulant should be applied. The first panel of seedling trees is opened at 20 inches from the ground, the second (up to recently) at 30 inches, and the later panels are of even greater height. This results in bark of different renewal on the same panel; the bark of first renewal gives a good response and that of second renewal lower down the stem a poorer response to stimulation.

On high level tapping when the cut moves towards the junction between virgin bark and bark of second, or poor first renewal, the

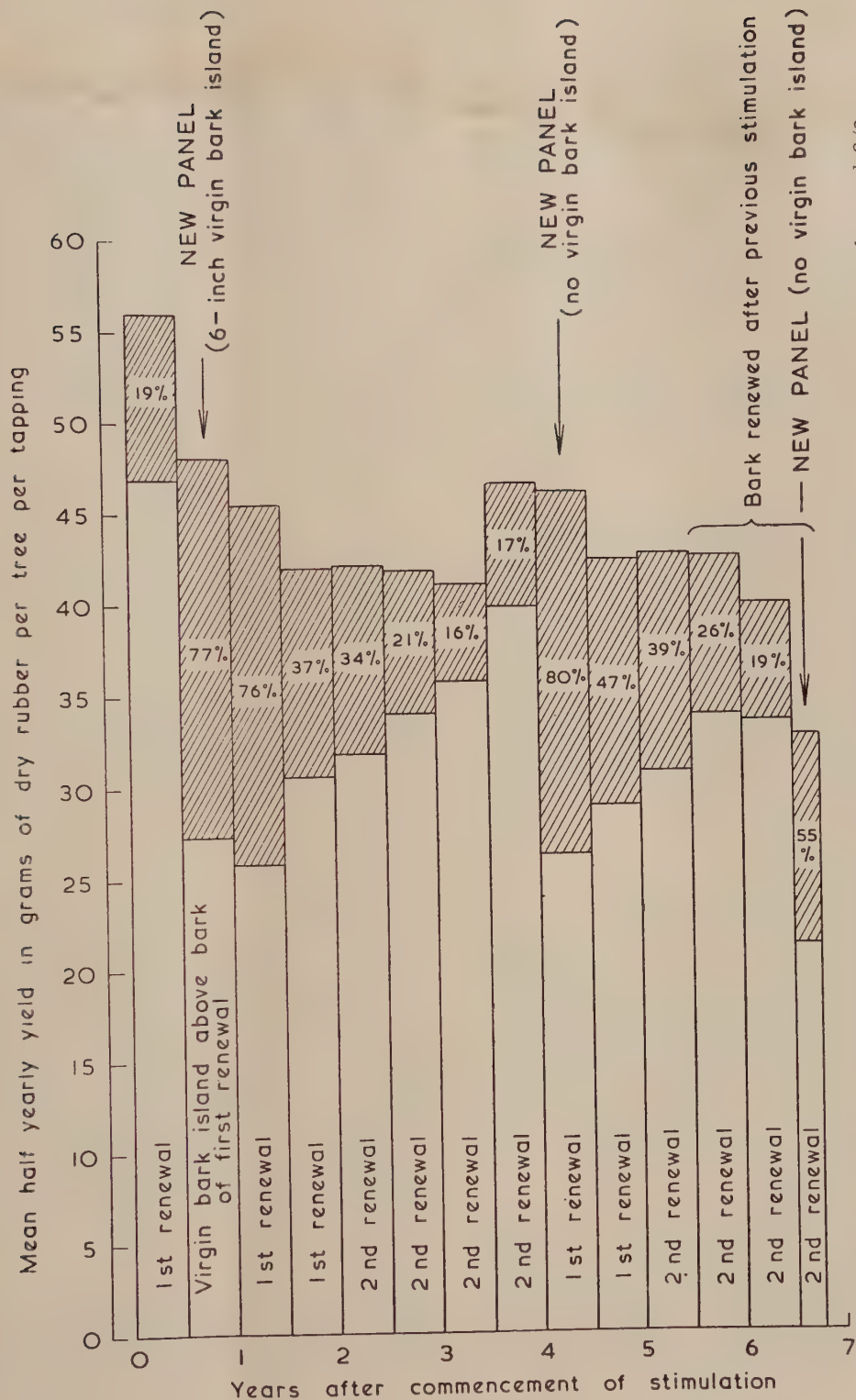


Figure 1. Effect of 2,4,5-T yield stimulant on yield of clonal seedlings, planted December, 1931, and tapped S/2. d/2. 100 per cent. Shaded portion shows extra yield obtained by stimulation. Dates of stimulant application were: first, February, 1952; second, November, 1952; thereafter, May and November each year.

response to stimulant application also shows a downward trend. A highly positive effect is obtained, however, when the actual virgin bark island is stimulated, as the yield of this bark on unstimulated control trees drops to a very low level.

We suggest that when low panels of clonal seedlings are tapped at 67 per cent. or 100 per cent. intensity, stimulation should be discontinued as soon as the cuts are within 1 foot of ground level.

When high panels are tapped, half yearly stimulation should continue and be intensified to once every three months when the cut is within 6 inches of the junction between virgin and renewed bark.

Yield Increases : Reactions of Different Planting Materials to Stimulant

In general no predictions can be made as to the increase in yield which may be expected after application of a stimulant ; much depends on the health of the trees and on local environment. Trees growing under poor environmental conditions do not respond satisfactorily, and it is often from such material that an increased output is desired. Poorly renewed bark of healthy trees also gives a disappointing response. The best results are obtained from well renewed bark, or from virgin bark at high level on trees which are in good heart.

Clonal Seedlings

On clonal seedling trees 20 years old at the time of the first treatment, we have recorded over a period of seven years a total increased yield of 36.5 per cent. following half-yearly stimulant application to good bark of first and later of second renewal (see *Figure 1*). The control trees were yielding at the rate of 876 lb per acre per annum, which means that a yearly increase of some 320 lb per acre was obtained at a total cost in stimulant application of less than \$12(M) per acre per year.

Unselected Seedlings

Unselected seedling trees tapped on high panels in virgin bark give a similar relative response, but as their actual yield level rarely exceeds 500 lb per acre per year the quantity of rubber obtained through stimulation is less than for clonal seedling trees.

Buddings

In general buddings react favourably to stimulation if tapping is done on high panels or in bark of good renewal. We have recorded an increased yield of 300 lb of rubber per acre per year over a period of five years in an experiment on mixed buddings, planted as budded stumps in 1930. Tapping is done alternate daily on a half-spiral cut in renewed bark, and a stimulant is applied at half yearly intervals. Clone AVROS 50 was the only clone that showed a disappointing response to stimulation under the conditions of this experiment. The evidence is generally not sufficient to demonstrate significant differences between clones in their responses to stimulant application.

Stimulation of Ladder-trapped Trees

Rubber trees should not be tapped on high panels if there is good bark of first renewal available at low level. We recommend that all virgin bark and bark of first renewal should be tapped out at normal height before opening trees for ladder tapping.

Experiments have shown that high panels may yield considerably less than low panels of good first renewal bark on both buddings and seedlings. Only if the bark of first renewal is considered too thin for tapping—this rarely occurs under good management—should high panels be opened.

Unselected Seedling Trees

Unselected seedling trees generally yield less when tapped on high panels than when tapped low down the tapering stems in renewed bark of reasonable quality. Ladder tapping of this planting material should therefore, as a routine estate practice, be combined with half yearly stimulant application from the moment the high panels are opened. This holds only for tapping at normal intensity. If sufficient bark reserves are available for a long period of double cut 200 per cent. intensity tapping, the use of a stimulant should be postponed until the final 2-3 years of tapping (see 'Intensive Tapping of Mature Rubber' in *Planters' Bulletin* 38, September 1958).

Clonal Seedlings

There is now evidence that clonal seedlings react more favourably to ladder tapping than do unselected seedlings. The yield on ladder

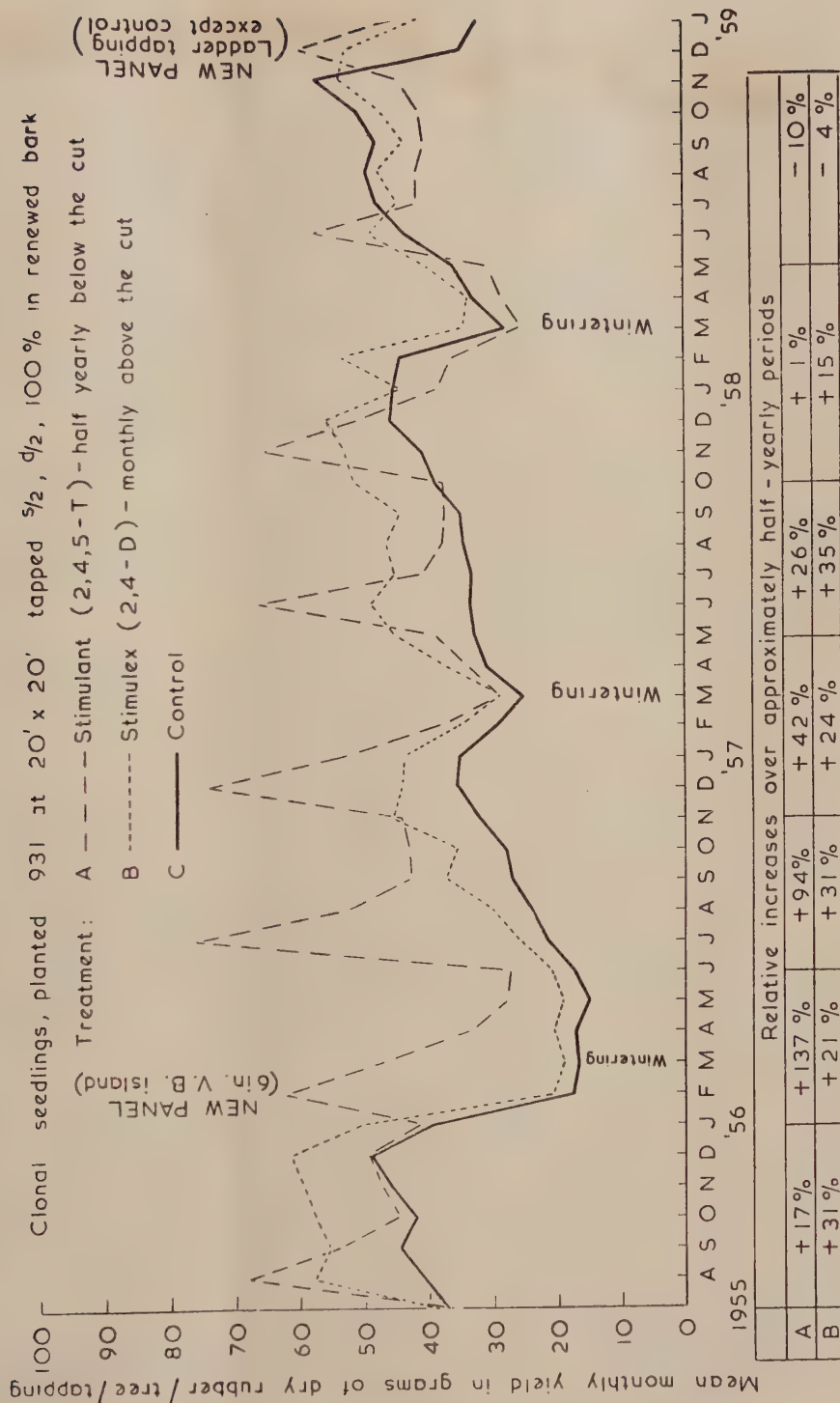


Figure II. The effect of two types of stimulation on monthly yields over a period of three and a half years. No stimulant was applied after November, 1958.

tapping is higher than that obtained when tapping second renewal bark low down the stem; this effect, however, is less striking than in certain clones mentioned below. We recommend application of a stimulant at half yearly intervals when tapping clonal seedlings on high panels.

Clones

A different approach to stimulation of yield should be followed when tapping budded trees on a high panel. Certain clones normally show a large increase in yield when high panels are opened, such as clones PB 186, Pil B84, Pil A44, PB 86 and Tjir 1.

The more recently developed clones have not yet been intensively tested for clonal reactions, since in most of our experiments these trees are still being tapped in bark of first renewal. In one experiment clone RRIM 501 is giving a very high yield on ladder tapping whereas all other clones give an unimproved or reduced yield during the second year of ladder tapping, compared with that obtained from first renewal bark during earlier years.

It appears that clones of high yield capacity when tapped in virgin bark at normal level, will again produce high yields when tapped on high cuts, especially after completion of tapping of first renewal bark at normal height. It is recommended that when high panels are opened on budded trees, no stimulant should be applied for a period of at least three months, so that it can be ascertained whether the particular clone will give a high yield on ladder tapping. If no favourable response is recorded, a stimulant should be applied at intervals of six months. This method has given satisfactory results on practically all clones. Clone PB 25, which in our experiments did not respond well to ladder tapping, has given outstanding yields when ladder tapping has been combined with stimulant application. If yields are high after opening for ladder tapping, we recommend postponement of stimulant application until a well defined downward trend sets in as the cut approaches the renewed bark. The period of high yields is largely determined by the height of opening (see *Planters' Bulletin* 43, July, 1959, 'Ladder Tapping of Budded Trees').

The Effect of Tapping System on the Response to Stimulation

Tapping Intensity

Tapping systems of low intensity such as S/2.d/3.67 per cent. and S/2.d/2.100 per cent. permit a better response to stimulation than do high intensity systems such as 2S/2.d/2.200 per cent., 3C/2.d/2.300 per cent. and 2C/1.d/2.400 per cent. The latter 'slaughter-tapping' system actually shows a negative response: after a peak yield lasting one month, the yield level drops to a level far below that of unstimulated trees tapped on the same system (see *Journal of the Rubber Research Institute of Malaya*, 1955, Vol. 14, Communication 296, page 387).

It is shown in *Planters' Bulletin* 38 (September 1958) in the article 'Intensive Tapping of Mature Rubber' that when tapping is on a double cut system at 200 per cent. intensity (2C/2.d/2.200 per cent.), stimulants are effective for only a limited period of 1½-2 years.

Comparing S/2.d/2.100 per cent. with S/2.d/3.67 per cent. tapping, it appears that the third daily system gives a better response, but the yield does not equal that of trees tapped alternate daily and also treated with a stimulant. A large saving in tapping costs will nevertheless be achieved by combining third daily tapping of a half-spiral cut with stimulant application.

Periodic Tapping

There is still no conclusive information about the response to stimulation under alternate daily periodic systems. Such systems have been reported to give satisfactory results if the stimulant is applied two to three months after the resting period, so that full advantage is taken of flush yield due to resting.

Daily periodic systems are not considered suitable for combination with stimulant application below the cut. Application of Stimulex above the cut to the bark tapped away during the preceding tapping period may prove satisfactory, but a low d.r.c. is expected at the end of the tapping period and the renewing bark will probably have a wavy appearance.

Full Spiral Tapping

We have not yet tested the effects of stimulants under the full spiral tapping system. This tapping system has largely lost its popularity in

Malaya because it interferes badly with girdling in young trees and because it is not conducive to a high standard of tapping.

Reports from estates indicate that a combination of a stimulant with this tapping system may result in bursts in the renewing bark above the cut and 'bleeding'—possibly due to an excessive dose of stimulant. We recommend that not more than 1-1½ inches of bark below the full spiral cut should be treated.

Full spiral tapping causes late dripping, and a stimulant is expected to increase this effect.

Further Observations on Response to Stimulation

Effect of Environment

Trees growing under poor environmental conditions do not respond well. It is often on such material that stimulants are applied in an effort to increase the crop from low-yielding fields.

Brown Bast

Brown bast incidence is not increased by the use of yield stimulants. If for some reason a tree goes dry after stimulant application, the treated strip of bark should be shaved away.

Rate of Flow

Yield stimulants gave a slight increase in the rate of latex flow, but the duration of flow is greatly increased during the peak yield period. If full advantage of the stimulant is to be obtained a second collection should be made especially during the first month after application, otherwise there may be a high proportion of cup-lump.

Precoagulation

High tapping gives latex of high magnesium content which increases precoagulation. This effect is often attributed to the use of a yield stimulant, as ladder-tapped trees are frequently so treated. However, yield stimulants tend to reduce rather than to increase precoagulation.

Dry Rubber Content

The d.r.c. of the latex declines during the periods when yields are stimulated, but increases again when the yield returns to normal, some three months after application of the stimulant below the cut.

Properties of the Latex

The properties of latex concentrate and dry rubber may be affected to some extent by the use of yield stimulants. The volatile fatty acid (VFA) production in a stimulated latex is about twice that in a normal latex and consequently the use of small additional quantities of anti-coagulants followed by quick processing should be adopted for latex from stimulated trees. VFA formation sometimes gives rise to additional fermentation bubbles in RSS; the addition to the diluting water of 2-4 oz. of formalin per coagulating tank is usually enough to correct the increased bubble formation. Stimulation sometimes causes increased enzymic discolouration for a short time after application of the stimulant, and care should be taken when using this latex for preparing pale crepe.

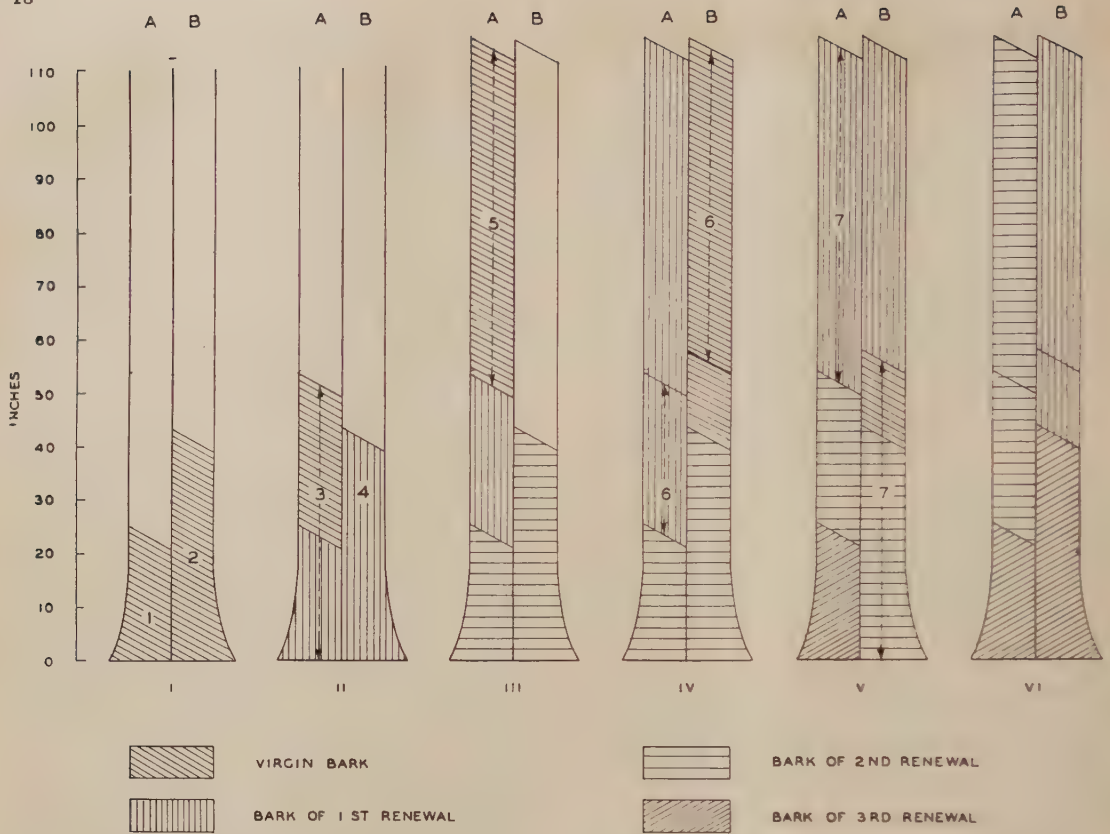
These effects on latex composition are small for tapping near the base of the tree and for low tapping intensities. They are greater for high tapping which gives rise to effects similar to those caused by stimulation. Moreover, VFA content, fermentation bubbles and enzymic discolouration all increase with greater intensity of tapping. More vigorous steps are then required to avoid ill effects which are due partly to the stimulation treatment and partly to the height of the cuts and to the intensity of tapping. These adverse effects are mitigated by the practice of bulking latices before processing, giving a mixture in which latex of normal composition predominates.

Suggested Schedules for Tapping and Stimulation of Yield

These schedules are represented in diagrammatic and tabular form in *Figures 3 and 4*. Roman numbers are assigned to successive phases of tapping both in the schedules below and in the figures.

Buddings—Tapping System S/2.d/2.100 per cent.

- I. Open the trees when 70 per cent. of the stand has reached tappable size at 50 inches above the union. The second panel to be opened at the same height at the opposite side of the trees. No stimulation should be done. This will give 10 years of tapping of virgin bark at normal height (A1 and B2).



<i>Diagram</i>	<i>Succession of panels</i>		<i>Bark. r.=renewal</i>	<i>Tappling system</i>	<i>Period of tapping, years</i>	<i>Stimulant application</i>
I	1st.	A1	Virgin	S/2.d/2. 100%	5	None
	2nd.	B2	"	"	5	None
II	3rd.	A3	1st r.	S/2.d/2. 100%	4½	Optional
	4th.	B4	" "	"	4½	Routine, ½-yearly
III	5th.	A5	Virgin	C/2.d/2. 100%	4½	Optional. Routine quarterly from 60 in. down to 50 in. (v.b. island)
IV	6th, { 2 cuts {	A6	2nd r.	2C/2.d/3. 133%	5	None
		B6	Virgin	"	5	Optional. Routine quarterly from 60 in. down to 50 in. (v.b. island)
V	7th, { 2 cuts {	A7	1st r.	2C/2.d/2. 200%	4	To both cuts during final 2 years of planting
		B7	2nd r.	"	4	
VI	Gives final bark position of trees					

Figure III. Suggested tapping schedule for buddings. Panels numbered in order of tapping.

- II. The third panel (A3) is opened in first renewal bark of the first panel. No virgin bark island should be created. Bark consumption when tapping renewed bark will be slightly greater. No stimulation should be done unless there is an urgent need for a temporarily increased crop. The fourth panel (B4) should be opened in the renewed bark of the second panel with routine half yearly application of a stimulant. The trees are then over 20 years old and will respond favourably without ill effects. A total of 9 years tapping of first renewal bark may be expected.
- III. A high fifth panel (A5), tapped alternate daily, should then be opened above the oldest bark of second renewal at 110 inches from the union. If no favourable response to ladder tapping is observed after three months, a yield stimulant should be applied at half yearly intervals, to be increased to quarterly applications when the cut comes within 10 inches of the junction between virgin and renewed bark. This will give $4\frac{1}{2}$ years of ladder tapping, up to the time when the cut has reached the bark of second renewal.
- IV. Tapping is continued into the renewed bark of the low panel (A6), but without stimulation, and at the same time a second high panel (B6) can be opened at the opposite side of the tree. Both cuts are tapped third daily, 2C/2.d/3.133 per cent. A stimulant should be applied to the high cut when the yield shows a downward trend as the cut approaches the renewed bark below. Stimulation should be half yearly at first and later quarterly, and should cease when the high cut crosses into the renewed bark. A period of 5 years of third daily double-cut tapping may be expected on these panels.
- V. At this stage the trees have been tapped for $28\frac{1}{2}$ years and will be some 35 years of age. Such fields will probably be considered for replanting. There is still bark of first renewal on the two high panels available and one low panel with bark of second renewal. One high (A7)

and one low panel (B7) could be tapped out together in four years of alternate daily double cut tapping (2C/2.d/2.200 per cent.) with half yearly stimulant application during the final two years of tapping, leaving another high panel of first renewal.

Seedlings—Tapping System S/2.d/3.67 per cent.

- I. Open the trees when 70 per cent. of the stand has reached tappable size at 20 inches from ground level (A1). Open the second panel at 40 inches from the ground at the opposite side of the tree (B2).
- II. The third panel (A3) is opened at 30 inches above the top mark of the first panel, hence at 50 inches from ground level. The fourth panel (B4) is opened in the renewed bark of the second panel at 40 inches from the ground. These four panels together will give a period of 18 years of third daily tapping, during which a stimulant should be used on the fourth panel, and may be used temporarily if the yield drops when the tapping cut approaches the junction of virgin and renewed bark on the third panel. Our experiments have shown a disappointing response to stimulant when the cut approaches ground level on seedling trees; it is advisable to discontinue stimulation when the cut reaches a height of one foot above the ground.
- III. When the low panels have been tapped out, a high fifth panel (A5) is opened at 110 inches from the ground, if branching allows, for third daily tapping of a half-circumference cut. This should be combined with half yearly application of a stimulant, to be increased to quarterly application when the cut comes within 10 inches of the renewed bark of the third panel. This will give 6 years of tapping on this panel.
- IV. After the cut reaches the renewed bark at 50 inches from the ground, tapping is continued into the low panel (A6) without stimulation, and at the same time a new high panel (B6) is opened. Both panels are tapped third daily (2C/2.d/3.133 per cent.). No stimulation should be

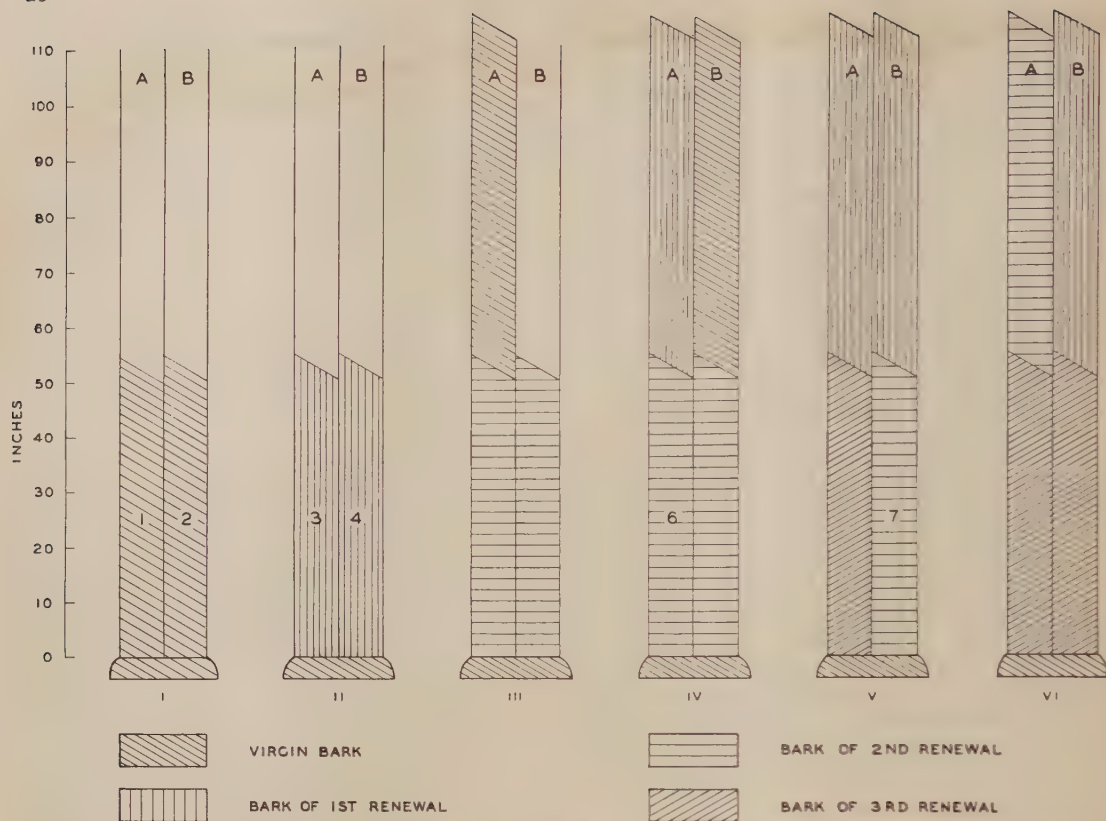


Diagram	Succession of panels	Bark. r. = renewal	Tapping system	Period of tapping, years	Stimulant application
I	1st, A1	Virgin	S/2.d/3 67%	2½	None
	2nd, B2	Virgin	"	5	None
II	3rd, A3	30 in. virgin 20 in. 1st r.	"	6	Temporary when crossing virgin bark island
	4th, B4	1st r.	"	4½	Routine ½-yearly down to one foot from ground level
III	5th, A5	Virgin	C/2.d/3 67%	6	Routine ½-yearly. Quarterly from 60 in. down to 50 in. (v.b. island)
IV	6th, 2 cuts { A6	30 in. 1st r. 20 in. 2nd r.	2C/2.d/3. 133%	5	None
	B7	Virgin	"	5	Optional
V	7th, 2 cuts { A7	1st r.	2C/2.d/2. 200%	4½	Quarterly to low cut from 50 in. down to 40 in. (v.b. island); routine ½-yearly to both cuts during final 2 years of tapping
	B7	Virgin and 2nd r.	"	4½	
VI	Gives the final bark position of trees				

Figure IV. Suggested tapping schedule for seedling trees. Panels numbered in order of tapping. Dotted lines indicate full length of tapping panels.

done until the yield from the high panel starts to drop as the cut moves towards the renewed bark underneath. A period of 5 years of double cut tapping may be expected on these panels. The high cut will then be between 15 and 20 inches above the renewed bark.

- V. At this stage the trees have been tapped for 29 years and the area will probably be considered for replanting. As in the case of the budded trees, there is still bark of first renewal on the high panels and also a 15-20-inch strip of virgin bark above an uninterrupted panel of second renewal at normal height. One high (A7) and one low panel (B7) can be tapped out together. The tapping intensity may be increased to alternate daily (2C/2.d/2.200 per cent.), with half yearly application of stimulant during the

final two years of tapping and quarterly application to the low cut as the strip of virgin bark is tapped away towards the bark of second renewal.

These suggested schedules are given as a guide but cannot always be put into effect. If the quality of bark of first renewal is poor, high tapping will have to be done first, followed by tapping of renewed bark. Also if wind damage or root disease curtail the life of a stand of rubber trees, intensive tapping with stimulation will have to be done at an early stage. Economic considerations may also enforce changes of tapping policy. Simultaneous change-over of tapping panels on all trees will greatly facilitate planning of tapping policy and sudden deviations from a fixed schedule. Uniformity in the field is a strict requirement for the proper execution of a programme in which stimulation and a double cut tapping system are combined.

OBSERVATIONS ON THE BIOLOGY OF A LEAF-CUTTER BEE "*Megachile frontalis*," IN NEW GUINEA

CHARLES D. MICHENER * AND J. J. H. SZENT-IVANY †

Megachile frontalis (Fabricius) (usually known in the past as *M. lachesis* Smith, see Liefinck, 1958) is the most conspicuous and probably the commonest leaf-cutter bee in the Territory of Papua and New Guinea. It is a large, elongate, black species that is sometimes of considerable importance because it cuts leaves of plants. It may also be a significant pollinator of certain plants. Aside from its economic significance, this species is of special interest because it is one of the rather elongate, parallel-sided species of *Megachile*, most of which do not use leaves in nest construction. *M. frontalis*, however, has cutting edges between the mandibular teeth of the female and cuts leaves for use in making its cells. Its systematic position will be discussed in a subsequent paper by one of us (Michener).

(Paper accepted for publication March 16, 1960.)

DISTRIBUTION

MEGACHILE *frontalis* and *M. atrata* Smith are closely allied species, if indeed they are specifically distinct, which together range from Malaya and Sumatra for over 4,500 miles across the Malay Archipelago to the Solomon Islands. *M. atrata*, which differs from *frontalis* by having yellowish rather than dark infuscated wings, is generally more western in distribution. Dr. M. A. Liefinck has kindly reported (*in litt.*, 10th August, 1959) this form from Malaya, Sumatra, Borneo, Java, and the lesser Sunda Islands of Bali, Flores, Sumba, Roti, and Timor. It is also known from the Philippine Islands (Luzon, Samar, Mindanao). *M. frontalis* is found, as shown by the localities listed below, for the most part east of the range of *M. atrata*. However, on Flores and Sumba, the two species, or at least forms with the two wing colors, both occur. This is the principal evidence now available, suggesting that the two forms are distinct species. Detailed anatomical studies have not been made.

The distributional data for *M. frontalis* (FIG. I) given below were gathered from the literature, from various collections, and from our field observations. Those data pertaining to the Territory of Papua and New Guinea are given in detail and summarized in FIG. II ‡ and those from other areas are sometimes given in a rather general manner, according to the details available. *M. frontalis* was found in all districts of the Territory of Papua and New Guinea, visited by Szent-Ivany during the past five years. In the list, localities not followed by any information in brackets are (except as otherwise noted) for specimens collected by Szent-Ivany (1954-1959) or by Michener (1959). This material is in the collection of the Department of Agriculture, Stock and Fisheries (Port Moresby), the Bishop Museum (Honolulu), and the Snow Entomological Museum, University of Kansas (Lawrence, Kansas). In brackets after other localities may be found (1), authors and dates, referring to publications listed in the "Literature Cited", or (2), the letter "L", referring to information provided by Dr. M. A. Liefinck (*in litt.*, 10th

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† Senior Entomologist, Department of Agriculture, Stock and Fisheries, Territory of Papua and New Guinea, Konedobu, Port Moresby.

‡ The following places mentioned by previous authors could not be located or identified, thus they are not shown on FIG. II.: Urikuturu, Kinigunang, Sinai and Suavi.



FIG. I.

August, 1959), or (3), letters referring to museum collections in which specimens of *M frontalis* were examined. These letters are B, Bishop Museum, Honolulu; AM, Australian Museum, Sydney; SAM, South Australian Museum, Adelaide; HSPA, Hawaiian Sugar Planters Experiment Station, Honolulu; USNM, United States National Museum, Washington; AMNH, American Museum of Natural History, New York; MCZ, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.

Territory of Papua

Central District: Aroa Plantation (Hisiu Beach Area); Koitaki (Koitakinumu Plantation), Sogeri Area [Cockerell, 1929]; Bisianumu (Rubber Experiment Station, 1,600 feet above sea level); Catalina Estate (Sogeri Area, 1,600 feet); Mororo Estate (Sogeri area, 1,700 feet); Gardens of the Corrective Institute and the War

Cemetery, Bomana (near Port Moresby); Experimental Blocks of the Department of Agriculture, Brown River; Daradai Plantation (Musgrave River area, 900 feet); Doa Plantation (Galley Reach area); Kapogere (Agricultural Station); Laloki (Plant Introduction and Quarantine Station); Port Moresby Town area (Boroko, Konedobu, Paga Hill—a number of specimens was collected by Mr. E. Guthrie and Mr. L. Jones in the Port Moresby town area in 1946 and 1947); Bisiatabu, Port Moresby [SAM]; Rigo; Roku; Urikituru to Sogeri [Cockerell, 1929].

Northern District: Kokoda (Coll. Mr. J. Healy); Mamoo Plantation (near Mount Lamington, 1,000 feet); Mount Lamington [AM, SAM].

Gulf District: Government Station, Kerema [Probably Kevema of Cockerell, 1929]; Aimei Trading Station near Port Romilly (coll. Mr. G. Rio).

Milne Bay District: Murua (Woodlark) Island and Kulumadau Hill, Murua Island [B, AMNH]; Fergusson Island [USNM]; Misima Island [SAM]; Mt. Sisa, Misima Island, 1,050 feet [AMNH]; Lusancay Islands; Kiriwina Island, Trobriand Islands; Rambuso, Sudest Island, sea level to 325 feet [AMNH]; Jinju, Rossel Island, sea level to 325 feet [AMNH].

Territory of New Guinea

Sepik District: Aitape [SAM]; Brandi (Intermediate School area), But (Frieze, 1912 b), Mandi and Tanbada villages in the Wewak Subdistrict; Bainyik Agricultural Station, Maprik (Government Station) and the areas of the following villages in the Maprik Subdistrict: Amahop, Apangai (No. 1), Aupik (No. 2), Bali (Garden of the South Sea Evangelical Mission), Bunahoj, Imbia, Kulabu, Kuminibus, Numakum, Numango, Wingei (No. 1), Wora (No. 1), Yamigum, and Yanago.

Madang District: Amele village cocoa plantation; Dugamoor Plantation (Bogia Subdistrict, coll. Mr. K. Mayer); Dylup Plantation; Kulili Plantation, Kar Kar Island; Madang (Friedrich-Wilhelmshafen) Agricultural Station; Reapi village; Bogadjim (Stephansort), S.E. of Madang [Frieze, 1909]; Erima (harbour of Bogadjim) [Frieze, 1909]; Astrolabe Range [SAM].

Morobe District: Bubia (Agricultural Experiment Station), Lae (Botanical Garden and secondary forest near "Didimans Creek"); Nasawampum village (20 miles N.W. from Lae); Busu River, east of Lae, 325 feet [B]; Boana Mission, Huon Peninsula [B]; Wau ("The Homestead" Coffee Plantation, 3,500 feet); Finschhafen [SAM]; Wareo, near Finschhafen [SAM]; Sattelburg (25 miles W. of Finschhafen) [Frieze, 1909]; Bulolo, 3,300 and 3,900 feet [B]; Komba [SAM]; Mount Gyifrie [SAM].

Western Highlands District: Kinjibi Plantation (Wahgi Valley, about 5,000 feet); Korn Farm (Agricultural Station, near Mount Hagen, 4,700 feet); Tsenga, upper Jimmi Valley, 3,900 feet [B].

Eastern Highlands District: Goroka (town area and coffee plantations of G. Pentland and R. & J. Frame); Koffena Plantation; Kori-feigu village; Lunapieve Plantation (Asaro Valley). Altitudes of these localities are 5,200-5,700 feet.

Manus District: Loni Village (Los Negros Island).

New Britain District (Neu Pommern): Keravat (Lowlands Agricultural Experiment Station); Kokopo; Baining, St. Pauls, Gazelle Peninsula, 1,140 feet [B]; Riella, north coast [B]; Talalo, Nakanai Mountains, 2,925 feet [B]; Kinigunang [Frieze, 1909]; Ralum [USNM] (Cockerell, 1911).

New Ireland District: Lagakot Plantation, Lihir Island; lower Kait River [B]; Gilingil Plantation [B].

Bougainville District: Kangu Hill (Buin, southern tip of Bougainville Island opposite Shortland Island of the British Solomon Islands Protectorate); Simai [AM]; Borioka, 975 feet [B]; Naval Air Base [Krombein, 1951]; Suavi [Cockerell, 1929].

British Solomon Islands

Guadalcanal: No further locality [B]; Tenaru [Krombein, 1949].

Florida: Siota [Krombein, 1949, 1951].

Tulagi: [Cockerell, 1936].

Malaita: Suu [Cockerell, 1936].

Dutch New Guinea

Djamna [MCZ]; Hollandia [Frieze, 1912 a]; Humboldt Bay (near Hollandia), [Frieze, 1909]; Manokwari [Frieze, 1909]; Pim, Jutefa Bay, sea level to 100 feet [USNM]; Misool Island [L]; Sabron, Cyclops Mountains, 930 feet [USNM]; Kaimana [USNM].

Indonesia

Kei Island.

North Moluccan Islands: Halmahera (Gilolo) [Lieftinck, 1958]; Ternate [L]; Batjan (Bachian) [Smith, 1860; L]; Obi [L].

South Moluccan Islands: Buru (Bouro) [Alfken, 1926; Lieftinck, 1958]; Ambon (Amboina) [B, L]; Ceram (Piru) [HSPA]; Saparua [Lieftinck, 1958].

Lesser Sunda Islands: Flores [L]; Sumba [L]; Tanimbar (Timorlaut) [L].

Celebes: Samanga [Frieze, 1909; L].

Frieze (1909) also records the species from Cairns, Queensland. Subsequent collecting in the area has not rediscovered it, but it may well occur there.

VARIATION

As indicated in the section on distribution, *M. atrata* may be only subspecifically distinct from *M. frontalis*. Even among forms currently referred to as *frontalis*, considerable variation exists. The Philippines form, which has received the subspecific name *nigrolateralis* Cockerell (1914), is probably the same as *atrata*. According to Dr. M. A. Lieftinck (*in litt.*, 10th August, 1959), specimens from Celebes have paler wings (grey, not fuliginous) than typical material.

Specimens from the Eastern and Western Highlands districts of New Guinea, collected at altitudes of 4,700 to 5,500 feet, and, curiously, also those from near sea level on the Lusancay Islands and Kiriwina Island in the Trobriand group, differ from those found elsewhere in New Guinea by the brownish-red rather than black scopa of the female and by the more extensive reddish pubescence on the apical terga of the male. Only one female out of nearly 100 studied from the highlands has a black scopa, but males are less consistently different. We know of no biological differences between these forms, but the biological observations described below are identified by localities and could thus be segregated in case differences appear after more-detailed study.

It is interesting to note that, according to Dr. Lieftinck, the red scopa reappears on the island of Sumba, in the Lesser Sunda group. He says that on that island the scopa may be red, black, or intermediate, but that red predominates. There are also specimens of *M. atrata* from Sumba and Timor with red scopal hairs. Except for this material and the populations from the New Guinea Highlands and the Trobriands, all known specimens of both *atrata* and *frontalis* have a black scopa.

TERRITORY OBSERVATIONS.

Seasonal Occurrence

There seems to be no marked seasonalism in the flight of *Megachile frontalis*, specimens having been taken in every month of the year. Not only have adults been taken at all seasons, but at Kerema on 8th May, 1959, and at Bisanumu on 12th May, all stages from eggs to young adults were found in cells. Continuous activity throughout the year is not surprising in an area all of which is less than 10 degrees from the equator.

Sleeping

At Goroka and Kerema "sleeping" individuals of both sexes were observed (by Michener). Occasional bees of both sexes were observed alone, on grass leaves, but the majority of those noted were resting on dead weeds rising above the general level of surrounding tall grass. The bees flew to these favoured locations between 4 p.m. and 6 p.m. (observations made 28th April to 1st May at Goroka), earlier if the day was rainy. They alighted, turned head downward on a small stem (or grass blade), grasped the stem with the mandibles and within half a minute to one minute became "asleep" so that they could be put into a bottle with little danger of their being disturbed and flying off. If dropped on the ground, some lay there while others flew off sluggishly. Even on the most densely occupied weeds, the bees were not crowded together. Each was a centimeter or more from its nearest neighbours. While the sexes often mixed, there was an obvious tendency for females to sleep in some groups and males in others. In the morning the bees took flight between 7 and 9 o'clock as they were dried by the sun.

On 28th April, 1959, a rainy afternoon, all the individuals which could be found in an area of 20 by 20 metres at Goroka were taken. There were about 30 of each sex, mostly on three tall dead weeds but a few were scattered elsewhere. The next evening, a similar number was in the same area, mostly on the same dead weeds. Perhaps they failed to reach their usual resting places on 28th April before heavy rain immobilized them. On 30th April and 1st May only two were seen. Apparently there were about 122 individuals sleeping in the area, 120 of which were taken in the first two nights. In nearby similar areas, no *Megachile* could be found sleeping.

One would expect that bees sleeping outside of nests in this way would be mostly males (as is the case with many species) or young females that had not yet started to nest. This is not the case with *M. frontalis*. Most individuals of both sexes had tattered wings, indicating considerable wear.

The sleeping places studied at Goroka and Kerema were not near nesting places, nor were they near leaves or flowers used for making and provisioning the cells.

At Madang, males only were observed by Szent-Ivany sleeping in a field of *Mimosa pudica*. The bees were not resting on these rather low plants but on two higher ones. One was *Stachytarpheta javanica* (Verbenaceae), the other *Paspalum conjugatum* (Gramineae). Thirty-seven were caught in one sweep of the *Stachytarpheta* plant at 6.20 p.m.

Flowers visited

Adults of *Megachile frontalis* were found on flowers of plants belonging to 10 different families. However, they seem to prefer flowers of Leguminosae, both woody and herbaceous species. The names of the plants visited are:

- Acanthaceae :
 Asystasia intrusa.
- Caricaceae :
 Carica papaya.
- Compositae :
 Cosmos sulphureus.
 Tagetes erecta.
 Zinnia elegans.
- Convolvulaceae :
 Ipomoea sp.
- Euphorbiaceae :
 Euphorbia pulcherrima.
- Labiatae :
 Ocimum basilicum.
 Ocimum canum.
 Hyptis sp.
- Leguminosae :
 Cajanus cajan.
 Cassia allata.
 Centrosema pubescens.
 Crotalaria anagyroides.
 Crotalaria gorensis.
 Crotalaria mucronata.
 Crotalaria retusa.
 Leucaena glauca.
 Mimosa pudica.
 Pueraria phaseoloides.
- Myrtaceae :
 Eugenia malaccensis.
- Polygonaceae :
 Antigonon leptopus.
- Sterculiaceae :
 Commersonia bartramia.
 Kleinbovia hospita.

No collection of pollen was observed on plants in families other than Leguminosae and it is probable that these are only nectar sources. In fact, pollen collecting was only observed on *Cajanus cajan*, *Crotalaria mucronata*, *Leucaena glauca* and *Mimosa pudica* but it is likely that the other Leguminosae are also pollen sources. Competition for visits by *Megachile* between

Mimosa pudica and *Leucaena glauca* was observed at Bisianumu, where *Megachile frontalis* was observed in large numbers collecting pollen from the flowers of *Mimosa*, but was not on those of *Leucaena*. However, *Leucaena* flowers were visited for pollen at Kapogere where *Mimosa pudica* was absent. Much more decisive evidence of competition among flowers for visits by bees has been gathered elsewhere (see, for example, Linsley and MacSwaine, 1947).

Injury to Leaves

Cutting of pieces of leaves for the construction of cells by *Megachile frontalis* was observed repeatedly in the Territory of Papua and New Guinea. The following plants were affected:

- Combretaceae :
 Terminalia catappa (Madang).
- Leguminosae :
 Cassia allata (Port Moresby). (See Plate 1.).
 Cassia fistula (Port Moresby).
- Lecythidaceae :
 Planchonia timorensis (Kulabu).
- Lythraceae :
 Lagerstroemia indica (Goroka).
- Myrtaceae :
 Eucalyptus deglupta (Goroka). (See Plate 1.).
 Psidium guajava (Doa plantation, Brandi Intermediate School area). (See Plate 1.).
- Rosaceae :
 Rosa spp. (Goroka, Kokopo, Wau). (See Plate 1.).
- Rubiaceae :
 Coffea arabica (Goroka, Lunapieve Plantation). (See Plate 1.).
 Gardenia sp. (Goroka).
 Timonius sp. near *rufescens* (Kulabu).
- Sapindaceae :
 Pometia pinnata (Madang).
- Sterculiaceae :
 Commersonia bartramia (Government Station, Maprik).
 Theobroma cacao (Lagakot Plantation, Lihir Island).

The extensive damage to *Eucalyptus deglupta* at Goroka has been described in two previous papers (Szent-Ivany, 1958; Szent-Ivany and Womersley, 1958). As a result of cutting of more or less symmetrical pieces from the leaves, the whole appearance of the trees was changed, the shape of the leaves resembling that of deciduous species of *Quercus*. (See Plate 1.).

Besides *Eucalyptus deglupta*, three ornamentals (*Lagerstroemia indica*, *Rosa* spp. and *Gardenia* sp.), and one fruit tree (*Psidium guajava*) were found severely damaged by *Megachile*



PLATE 1.

frontalis. Extensive damage to rose bushes was caused in the manager's garden at the Animal Industry Station at Goroka, in July to October, 1955. It was observed that the bees had their nests at a distance of several hundred yards from this garden. The nests were built in the side of a ditch which formed the western boundary of the airstrip. Hundreds of nests were found here. Several nests were examined and most of them had parts of rose leaves in the cells. There were no rose bushes between the area of the nests and the Animal Industry Station.

The female bees were very active between 9 and 11 a.m. on a bright sunny day and it was easy to follow the route of their flight between the rose garden and the drain. Bees coming out of their nests flew straight in the direction of the station garden and most of them came

from that direction back to their nests. All the way from the ditch to the garden one could see the bees flying rapidly back and forth.

Some *Gardenia* trees in the Goroka town area were almost stripped by females of *Megachile frontalis*.

Minor damage in patches was observed on *Theobroma cacao* at Lagakot Plantation and on *Coffea arabica* at Lunapieve Plantation and at Mr. R. Frame's Plantation at Goroka, where some young coffee trees were severely stripped, causing a slight setback in growth.

Chemical control is not easy. The most successful treatment is to apply BHC in the form of "Gammexane 10" dust. The application has to be repeated at intervals of two or three days. However, the dusting of coffee and cacao bushes with Gammexane is not recommended, because it appears to cause an "off-flavour" to the beans.

Near Kulabu *M. frontalis* was observed attacking leaves of two secondary forest trees, *Timonius* and *Planchonia*.

NESTING AND BREEDING

Nest Locations

A. R. Wallace (in Smith, 1871) noted that this species "makes a small round hole in hard clayey ground." L. J. Toxopeus (in Alfken, 1926) recorded observations on a large number (thousands) of nests in an earth bank. He observed the bees carrying pieces of leaves as well as pollen into these holes. Szent-Ivany (1958) recorded the species (under the heading "*Megachile* sp.") nesting in large numbers in lawns and tennis courts in New Guinea (Kinjibi Plantation, Western Highlands).

We have observed nests at Port Moresby (Paga Hill), Bisianumu, Kerema, Goroka, and several places in the Maprik subdistrict (Sepik District).

As reported by the authors cited above, the nests consist of burrows in the ground. Scattered ones are found in flat ground, either bare or covered with short grass. Bare village squares in the Maprik subdistrict were found to be favourable sites (Plate 2). However, nests often occur in much larger numbers in earth banks, e.g., roadside banks near the villages of Kulabu and Kuminibus, Maprik subdistrict (Plates 2 and 3, Figure III), the sides of roadside ditches at Kerema and near the village of Kulabu, the side of a ditch along the airstrip at Goroka and small roadside banks at Bisianumu. At Kerema, there were about 100 nests in a bank about 18 inches high along a ditch 10 yards in length. At Bisianumu, many old cells were exposed by erosion of banks, indicating that they had been in use for a long time.

At all locations mentioned, the nests of the *Megachile* were in heavy soils. This preference is emphasized by the following observations made at Kulabu. A shallow ditch (Fig. III) about two feet wide separated a road from a clayey roadside bank. The ditch was full of sand, probably brought from the nearby river when the road was constructed. Large numbers of *Bembix melancholica* Sm. but no *Megachile* were nesting in the sandy soil. In the clayey soil were large numbers of nests of *Megachile frontalis* but no nests of *Bembix*.

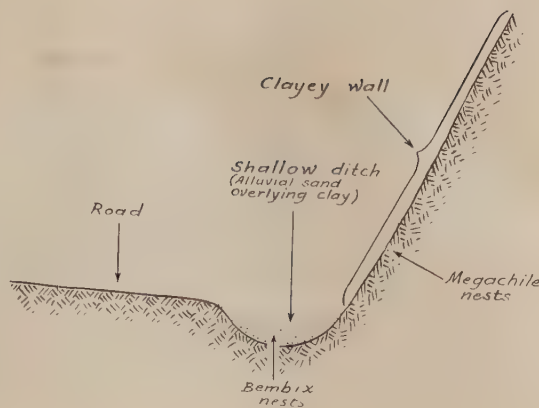


FIG. III.

Construction and Activities Around Nests

Unlike most species of *Megachile*, *M. frontalis* digs its own burrows. Females have been seen starting burrows where there was no previous hole, both on flat ground and in vertical banks. In digging, the females work largely with their mandibles. In rather moist soil at Kerema, excavating females were observed to carry out a pellet of earth once every 45 to 90 seconds (average, about once a minute). The pellets are irregular, up to about 3 mm. in diameter. The bee comes out of the nest head foremost, carrying a pellet in her mandibles, and flies 150 to 300 mm., drops it, and returns to the nest.

In bright, sunny weather both male and female *Megachile frontalis* were very active around the nests in the roadside banks near the villages of Kulabu and Kuminibus. However, the males settled down on nearby plants as soon as clouds covered the sun. The females continued cutting leaves, carrying leaf sections and pollen into their nests even in rainy weather. They stopped flying when the rain became strong or during sudden tropical downpours. Similar observations were made at Kerema.

In May, when observations of groups of nests were made at Kerema and Bisianumu, females were more abundant about nests than males. At Kulabu and Kuminibus in July, however, the number of males around the nests was much larger than that of the females. The proportion of females and males at the clayey wall near Kulabu village was estimated to be one to three. The males were actively flying

around the nests and up to three males were seen following a female (carrying pollen or leaf sections) into the nest. The females, which were actively building their nests or carrying pollen into them, appeared to be rather hostile towards the males. Males were often seen crawling into a nest which was not occupied at the time by a female. When a leaf-carrying female arrived at the entrance of a nest out of which a male was crawling, she appeared to be disturbed and vigorously chased the male away.

The parasitic bee, *Coelioxys intrudens* Smith (det. G. E. Nixon), was observed in large numbers hovering around the nests. Szent-Ivany often saw the head of a female *Megachile* in the entrance of a nest when a male *Megachile* or a female *Coelioxys* tried to enter it. Two or three quick vertical movements of the large head of the female *Megachile*, accompanied by horizontal movements of its large mandibles were enough to frighten away the smaller male *Megachile* or female *Coelioxys*. On one occasion a large brown gryllid (*Acheta* sp. ? Det. P.M. Stock) was observed entering a *Megachile* nest.

When half of the body of the gryllid was in the entrance hole, the female *Megachile* which occupied the nest pushed it out with a quick movement. The cricket stopped in front of the entrance and did not leave until the female *Megachile* attacked it several times. On attacking the large cricket, the female *Megachile* did not use her sting—she attacked only with the mandibles.

Mating

Males of *Megachile frontalis* were frequently seen on grass stems next to entrance holes as though waiting for females returning to or leaving the nests. Males usually attacked any female leaving the nest. On several occasions three or four males were seen to attack a single female. Sometimes they pushed the female down to the ground and one of the males copulated with the female on the ground. Several matings were watched and copulation was estimated to last 20 to 25 seconds. While they copulated, several other males were seen hovering around the mating pair. On one occasion Szent-Ivany put a cyanide killing bottle over a copulating pair and left it there until both were dead. As soon as the killing bottle was lifted and the

PLATE 2.





PLATE 3.

dead male was removed from the ground, another male lit on the back of the dead female and tried to copulate, while two other males were hovering above.

Nest Structure

Burrows examined ranged from 40 to 150 mm. deep. In soft moist soil at Kerema none (except those being constructed) was under 100 mm. in depth. The shallowest burrows studied were in hard, dry soil at Port Moresby. In diameter, burrows ranged from 14 to 16 mm., often irregularly larger near the entrances, perhaps due to washing by the heavy rains.

Burrows were sometimes simple, although deeper ones were often branched. From relative ages of larvae, it seems that each bee (at Kerema) makes a rather deep burrow, fills the inner portion with two to four cells end to end in a series, then often makes one or two short side branches starting at the cap of the last cell and sometimes bending back toward the entrance of the burrow. Each side branch is filled with one or two cells. The existence of short burrows (Port Moresby), deep enough for only one or two cells, indicates that a bee may make more than one nest during her life.

In a bank, burrows may be horizontal, but often slant downward. In flat ground, they always slant down; they are not vertical.

Cells

The cells are found in horizontal or slanting positions. In outside dimensions they are 23 to 32 mm. long, 12 to 16 mm. wide (Plate 3). The outer layer of leaves usually consists of 11 to 16 thick pieces, rather irregularly shaped,

each 13 to 16 mm. long by 11 to 13 mm. wide. The piece at the bottom of the cell, presumably the first put in place, is nearly round. Inside the outer layer of leaves is a layer, 0.5 to 1.5 mm. thick, of fine mud, well-smoothed on the inside. Female bees, presumably collecting mud, have been seen beside muddy puddles at Goroka. Inside the mud is a thin layer of leaves which must be soft and pliable when put in place, for each is neatly concave in inner aspect. There are about four elongate pieces (11 to 15 mm. long, 7 to 9 mm. wide) forming the side walls of this inner layer and a single round piece, bowl-shaped, about 7 mm. in diameter, forming the bottom of the inner layer. The inside dimensions of the cell are 13 to 16 mm. in length, 8 to 10 mm. in width.

The provisions consist of firm, rather dry, pollen, filling the bottom 5 to 6 mm. of the cell. The egg (Plate 4 and Fig. IV) is placed on top of the provisions. One end is inserted at the edge of the food mass, while the other extends beyond the middle of the surface of the provisions but does not touch it.

The cap of the cell consists of one or two inner, irregularly round leaf fragments about 9 mm. in diameter. They may be, but are not always, of thin, soft material like the inner layer of the cell. Outside of this is a layer (1 to 2 mm. thick) of masticated leaf material, followed by two or three more round leaf pieces, 9 to 10 mm. in diameter. Outside this is a thin layer of mud or mud mixed with masticated leaf material. A sectional view of a cell and its cap is shown in Fig. IV.



FIG. IV.

If the cells are in series, the base of the next cell rests against this mud layer, which is concave externally to fit the convex base of the cell. The cells are all similarly shaped, the first not more convex at its base than the others.

When the larva reaches maturity it covers the inner walls of the cell, except for a small space in the center of the cap, with a layer of yellowish faeces one fourth to one half of a millimeter thick. No evidence was noted of faeces being deposited before the larva reached maturity, as in other *Megachile*, but further observations should be made on this point. The cocoon is very thin, whitish, one layer thick, made of fine, white fibres with an amorphous substance filling the spaces between them. In texture, the cocoon is soft, delicate, flexible. Often there is a small hole in it at the anterior end, and the inner leaf of the cap may be chewed at this point. The tendency for the mature larva to chew the centre of the cap has also been noted in *Megachile brevis* Cresson (see Michener, 1953).

Associates

Females of *Coelioxys intrudens* Smith (det. G. E. Nixon) were found about *Megachile frontalis* nests at Kuminibus, Kulabu, and Wewak, all in the Sepik District, and at the former village a *Coelioxys* was seen to enter a *Megachile* nest, in which she remained for two minutes.

At Kerema, two adult females of *Miltogramma species* near *fasciata* Meigen (det. F. G. Fennah) were found about the nest openings, and in some old cells some puparia, possibly of the same fly, were found. These sarcophagids probably feed on the food stored in the cells of the *Megachile*. Adults and puparia of a presumably different species of *Miltogramma* were found in similar situations at several localities in the Sepik District.

In the latter area adults of *Plagiostenoptera acnea* (Wiedemann), a dipteran of the family *Platystomatidae*, were also found around the nests.

A mutillid, *Timulla (Trogaspidia) fervida* Smith, was found crawling in and out of nests at the Catalina Estate.

On many of the bees, especially on the propodeum and base of the abdomen, were numerous hypopi of a glyciphagid mite, probably belonging to the genus *Chaetodactylus* (det. J. H. Camin).

SUMMARY AND CONCLUSIONS

Megachile frontalis (Fabricius) is a common species in the Territory of Papua and New Guinea, as it is in most of the rest of the eastern half of the Eastern Archipelago. It is active throughout the year, visits a wide variety of flowers, apparently preferring legumes as pollen sources, and cuts leaves of many species of plants for nesting material. It is sometimes a significant pest because of destruction of leaves of *Eucalyptus* and other plants. It is a parallel-sided species. Most such species do not cut leaves.

Noteworthy features of the behaviour of *M. frontalis*, by which it differs from most other species of *Megachile* whose biology is known to us, are enumerated below :

1. It constructs its own burrows in the soil, often in aggregations. Most megachilids, and particularly species of *Megachile*, make use of pre-existing cavities or construct cells in the open. It is interesting that one other megachilid that digs its own burrows, the European *Anthocopa cristata* (Fonscolombe), also carries the excavated soil away from the nest in pellets (Ferton, 1893). This contrasts with most burrowing bees, which leave the



PLATE 4.

- excavated soil near the nest entrance. Other species of *Megachile* are known which usually dig their own burrows [e.g., *octosignata* Nylander (Ferton, 1909), and *circumcincta* Kirby (Ferton 1908)].
2. The cells consist of two layers of leaves separated by mud. Some other, quite unrelated species also use mud between layers of leaves or petals [e.g., *M. azteca* Cresson (Friese, 1924)].
 3. Round pieces of leaves are used at the bases of the cells as well as in the caps. Chewed leaf material is also used in the cap, together with mud. The use of chewed leaf material or vegetable paste is very common in species of other megachilid genera (e.g., *Hoplitis*) and some *Megachile* use such paste in conjunction with pieces of leaves [e.g., *M. sericans* Fonscolombe (Ferton, 1901)].
 4. The cocoon is thin and delicate, without coarse fibres in the anterior end, and is surrounded almost completely by a thin layer of faecal material.
 5. Mating occurs, at least part of the time, not on flowers but near the nests.

ACKNOWLEDGEMENTS

We wish to express our appreciation to Mr. J. S. Womersley, Chief of the Division of Botany, Department of Forests, Lae, for the

identification of plants mentioned in this paper; to Mr. H. Standfast, Assistant Malariologist, Department of Public Health, Maprik, who helped Szent-Ivany in the collecting of *Megachile frontalis* and other insects associated with this species; to Mr. Frank Ryan, District Agricultural Officer, Kerema, whose hospitality made possible the authors' studies there; to Dr. D. Shaw, Principal Plant Pathologist, of the Department of Agriculture, Stock and Fisheries, Port Moresby; to Mr. W. Forster of the Commonwealth Department of Civil Aviation, Port Moresby; and to Mr. and Mrs. Carl W. Rettenmeyer of the University of Kansas for making some of the photographic illustrations.

The field work done by Michener in New Guinea was made possible by a grant for study in Australia from the Fulbright Programme of the United States Government, administered through the United States Educational Foundation in Australia, and by travel funds provided by the programme on "Zoogeography and Evolution of Pacific Insects" (National Science Foundation grant G 4774 to the Bishop Museum, Honolulu, Hawaii) under the direction of Dr. J. Linsley Gressitt.

For identification of various associates of the *Megachile* we are much indebted to Messrs. R. G. Fennah, R. W. Cressky, G. E. Nixon, and

P. M. Stock, all of London, and Dr. J. H. Camin, of the University of Kansas. The identifications are individually credited in the text.

We are especially indebted to Dr. M. A. Lief tinck, of the Rijksmuseum van Natuurlijke Historie, Leiden, Holland, for references to certain publications and for data on the distribution and variation of *Megachile frontalis* and *atrata* and to Mr. Karl V. Krombein, of the United States Department of Agriculture, Washington, D.C., for distributional data from specimens of *M. frontalis* in the United States National Museum.

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EXPLANATION OF FIGURES

Fig. I. Map showing the range of *Megachile frontalis* (prepared by Mrs. M. L. Szent-Ivany).

Fig. II. Map showing the range localities where *Megachile frontalis* has been found in the Territory of Papua and New Guinea (prepared by Mrs. M. L. Szent-Ivany).

Plate 1. Leaves cut by *Megachile frontalis*. Top left, injury to climbing rose (*Rosa*) in garden near Wau; top centre, injury to *Cassia fistula* in garden, Port Moresby; top right, injury to coffee (*Coffea arabica*) in plantation near Goroka; lower left and lower right, injury to *Eucalyptus deglupta*, Goroka; lower centre, injury to guava (*Psidium guajava*), Doa Plantation, Central District of Papua.

Fig. III. Diagram of nesting site of *Megachile frontalis* and *Bembix* sp. near Kulabu village, Maprik subdistrict, New Guinea.

Plate 2. Nesting sites of *Megachile frontalis* in the Maprik subdistrict, New Guinea. Upper left, typical village showing flat, trampled ground in which many *Megachile* nest; upper right, nest holes in village square shown at left; lower left and right, roadside banks near Kulabu and Kuminibus villages showing many nest entrances.

Plate 3. Left, a cell of *Megachile frontalis* removed from the soil. The scale at the bottom is in millimetres. Right, leaf fragments from cells of the same species, showing, from left to right a, the lowermost

(rounded) fragment from four cells; *b*, ten of the irregularly-shaped fragments from the outer layer; *c*, the round pieces forming the bottom of the inner lining of two cells; and *d*, four of the elongate pieces forming inner linings. Two of the last were unavoidably torn in separating them for photography.

Plate 4. *Megachile frontalis*. *Left*, larva in process of pupating, small prepupa, large mature larva, small larva, and egg; *centre*, pupae, males above and

below, female in middle; *right*, adults, male above, female below.

Fig. IV. Diagramatic sectional view of a cell of *Megachile frontalis*, with base of next cell in the series above it. Heavy lines represent thick leaves, light lines, thin pliable leaves. The dotted area represents the food stores on top of which is the egg; areas shaded with slanting lines represent mud; the cross-hatched area represents masticated leaf material.

A Strain of Melon Mosaic Virus on "Cucurbita Moschata Duchesne" in New Guinea*

R. VAN VELSEN†

The virus attacking Cucurbita moschata Duchesne at Keravat, New Britain, is a strain of melon mosaic virus. The host range is restricted to the systemic infection of Cucurbitaceae, including Trichosanthes anguina L. and local lesion reaction on Chenopodium amaranticolor Coste et Reyn. The thermal inactivation point lies between 57 and 60 degrees C. for an exposure of 10 minutes, dilution end point between 10^{-3} and 10^{-4} , and longevity in vitro, 72 to 96 hours. The virus is sap transmissible and is also transmitted by an aphid, Aphis gossypii Glover.

BEFORE the studies of Lindberg, Hall and Walker (1956) there was much confusion with the identification of cucurbit viruses of limited host ranges. Frietag (1952) reported that he was able to differentiate seven distinct cucurbit viruses on the basis of symptoms, insect vectors, and physical properties, but gave no results. Lindberg *et al* made a critical comparison of the cucurbit viruses, found in the United State, with limited host ranges and divided them into two main groups—squash mosaic viruses and melon mosaic viruses—on the basis of host range, insect vectors, and physical properties.

At the Lowlands Agricultural Experiment Station at Keravat, New Britain, in the Territory of Papua and New Guinea, a mosaic disease on *Cucurbita moschata* Duchesne growing in the field was observed, and the following investigations were carried out to determine the identity of the virus.

SYMPTOMS INDUCED BY THE VIRUS

a. *Cucurbita moschata*.

Following the mechanical inoculation of the cotyledons, the young leaves emerging exhibited typical mosaic symptoms. On old plants the leaves are reduced to tendrils, with a little lamina present at the point of attachment of the petiole. Infected plants are slightly stunted compared with healthy ones, and bear normal flowers and fruit.

b. *Cucumis sativus* L. variety "palmetto".

The first true leaves appearing after the mechanical inoculation of the cotyledons show

typical mosaic symptoms which increase in extent and intensity in subsequent leaves. The leaves are greatly reduced in size and are severely distorted. The petioles and stem internodes are reduced to such an extent as to give the plant a rosette appearance. Flower development is extremely poor, and no fruit is set. The mosaic symptoms develop within seven days.

- c. *Citrullus vulgaris* Schrad. variety "Black Boy". Inoculated plants exhibit a dark green systemic mosaic pattern on the leaves with a general stunting of the whole plant.
- d. *Trichosanthes anguina* L.

The first true leaves, appearing after the inoculation of the cotyledons, develop a typical mosaic pattern, which becomes systemic. The infected leaves are reduced in size and are distorted by the presence of raised blisters on the leaf surface.

- e. *Chenopodium amaranticolor* Coste et Reyn. The test plants were mechanically inoculated when six leaves were present. Within three days, pale green spots were observed on the inoculated leaves, developing within the following two days into dirty, white-centred local lesions with a reddish-purple border. The lesions were not systemic, and did not produce any systemic infection.

EXPERIMENTAL RESULTS

a. Host range of the virus.

The test plants were grown in sterilized forest soil in 4-inch pots in insect-proof cages. Twenty young plants of each species were inoculated mechanically on the cotyledons, in

* Received for publication 20th October, 1959.

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the case of the cucurbit hosts, and on four young leaves of the remaining hosts, with the aid of 500 grit Carborundum and infectious crude sap from diseased *Cucurbita moschata*. After 28 days, leaves were taken from the test plants from above the point of inoculation, and ground. The juice was extracted by squeezing through muslin and mechanically inoculated on to *Chenopodium amaranticolor*.

Only plants belonging to the family Cucurbitaceae became systemically infected, with local lesion reaction on *Chenopodium amaranticolor* (Table I).

TABLE I.

Reaction of various hosts to inoculation with sap of the Keravat strain of melon mosaic virus.

Hosts	No. Plants Inoculated	No. Plants Infected
<i>Citrullus vulgaris</i>	20	16
<i>Cucurbita moschata</i>	20	12
<i>C. maxima</i> Duchesne	20	14
<i>C. pepo</i> L.	20	12
<i>Cucumis sativus</i> var. "Palmetto"	20	20
<i>C. melo</i> L.	20	20
<i>Trichosanthes anguina</i> L.	10 +	9
<i>Nicotiana tabacum</i> L. ...	20	—
<i>N. glutinosa</i> L.	20	—
<i>Datura stramonium</i> L.	20	—
<i>Vigna sinensis</i> Savi	20	—
<i>Zinnia elegans</i> Jacq.	20	—
<i>Lycopersicon esculentum</i> Mill.	20	—
<i>Phaseolus vulgaris</i> L.	20	—
<i>Petunia hybrida</i> Vilm.	20	—
<i>Chenopodium amaranticolor</i>	20	20 LL

— indicates no symptoms or recovery from inoculated plants.

LL indicates local lesions.

+ sufficient seed for only 10 plants.

b. Physical properties.

The resistance of the virus to exposure at various temperatures for 10 minutes, to ageing *in vitro* at room temperature (28 degrees C.), and to dilution was studied by the usual methods. *Cucurbita moschata* was the source plant of the virus and *Cucumis sativus* variety

"palmetto" was used for the test plant. The virus was active after an exposure of 57 degrees C. for 10 minutes, but inactive after an exposure of 60 degrees C. (Table II). It was inactivated after an exposure of 96 hours at room temperature (28 degrees C.), (Table III), and was inactivated when diluted to 10^{-4} , but active at a dilution of 10^{-3} (Table IV).

TABLE II.

Infectivity of the Keravat strain of melon mosaic virus when heated for ten minutes at various temperatures (degrees centigrades).

Temperature	No. Plants Tested	No. Plants Infected
Control	60 +	60
45	60	60
50	60	60
53	60	60
57	60	30
60	60	—
70	60	—
80	60	—

+ three tests each of 20 test plants.

— indicates no infection.

TABLE III.

Infectivity of infective extract of the Keravat strain of melon mosaic virus when aged at room temperature for various periods.

Time of Explosive in Hours	No. Plants Tested	No. Plants Infected
0	60 +	60
24	60	27
48	60	12
72	60	6
96	60	—
120	60	—

+ results of three tests each of 20 plants.

— indicates no infection.

TABLE IV.

Infectivity of various dilutions of infective sap of the Keravat strain of melon mosaic virus.

Dilution	No. Plants Tested	No. Plants Infected
	60 +	60
10^{-1}	60	60
10^{-2}	60	15
10^{-3}	60	6
10^{-4}	60	—
10^{-5}	60	—

+ results of three tests each of 20 test plants.

— indicates no infection.

c. *Insect transmission.*

Virus-free wingless adults of *Aphis gossypii* Glover were starved for one hour and then allowed an access feed of two hours. The aphids were placed on test plants of *Cucumis sativus* var. "palmetto" in groups of 10 and were allowed to remain for 24 hours. The plants were then dusted with D.D.T. After 28 days, 16 of the 40 test plants had developed mosaic symptoms. No specimens of *Myzus persicae* were found in the area.

DISCUSSION

Since no serological tests were possible due to the lack of equipment, the main criterion used in identifying the virus investigated is the host range test. Lindberg *et al.* differentiated squash mosaic, melon mosaic and cucumber mosaic viruses on host range, and physical properties. The virus investigated systemically infected only members of the family Cucurbitaceae, thus distinguishing it from cucumber mosaic virus. Thus the virus is a strain of squash or melon mosaic virus.

Considering the host range, physical properties and insect transmission studies, the virus is similar to melon mosaic virus as reported by Lindberg *et al.* However, the symptoms recorded on *Cucumis sativus* and *Citrullus vulgaris* vary from those recorded by Lindberg *et al.* Thus the author considers that the virus attacking *Cucurbita moschata* in New Britain is a strain of melon mosaic virus.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the identification of *Cucurbita moschata* by the Botanist, Division of Botany, Department of Forests, Lae; Dr. J. J. H. Szent-Ivany and Dr. Eastop for the identification of the aphid vector, *Aphis gossypii*.

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A New Species of *Planococcus* Ferris (Coccoidea: Homoptera) on Yams in New Guinea

D. J. WILLIAMS *

The following species, submitted for identification by Dr. J. J. H. Szent-Ivany of the Department of Agriculture, New Guinea, has been causing severe damage to yams, especially to the roots in storage. It differs in a few characters from all the known species of Planococcus and is described below as new.

The holotype is deposited in the British Museum (Natural History).

PLANOCOCCUS DIOSCOREAE SP. N.

Recognition characters

Adult female oval, attaining a length of 2.5 mm.; anal lobes moderately developed. Legs well developed, slender, hind coxae and tibiae with a few translucent pores. Circulus rectangular. Ostioles with inner edges of lips sclerotized and with 2-3 setae and a few trilocular pores on each lip. Anal ring with six setae, these about twice as long as diameter of ring. Cerarii numbering 18 pairs, each with a pair of conical setae which tend to be flagellate distally. Anal lobe cerarii each with a small area of sclerotization between the setae and accompanied by about 12 trilocular pores and three auxiliary setae. Anterior cerarii each accompanied by about eight trilocular pores and with space between setae lightly sclerotized.

Dorsal setae ranging from minute and slender to same size as cerarian setae, the latter type usually with 2-4 trilocular pores at the base and sometimes in pairs giving the appearance of dorsal cerarii, these present on all segments except the last. Dorsal tubular ducts of oral collar type confined to marginal areas of, at most, two posterior abdominal segments, often absent entirely. Trilocular pores not numerous.

Ventral surface with cisanal setae slender and about half the length of anal ring setae. Anal lobe bar slender, reaching to base of anal lobe setae. Anal lobe setae about twice as long as anal ring setae; bar setae situated towards anal lobe setae and about same length as cisanal setae.

Ventral setae not numerous, longer than dorsal setae and all slender. Multilocular disc pores arranged in transverse rows on abdomen at posterior edges of segments. On the eighth segment they are in a more or less double row and anteriorly they lie in single rows. A single row also

present on anterior margin of eighth segment and occasional pores present in anterior submedian areas of other abdominal segments. Altogether there are 125-160 pores. Tubular ducts of oral collar type smaller than those of dorsum, in transverse rows on abdominal segments and numerous in groups around the margin including the head. Ducts also present around coxae but groups around procoxae not continuous with marginal groups of prothorax. Trilocular pores sparse.

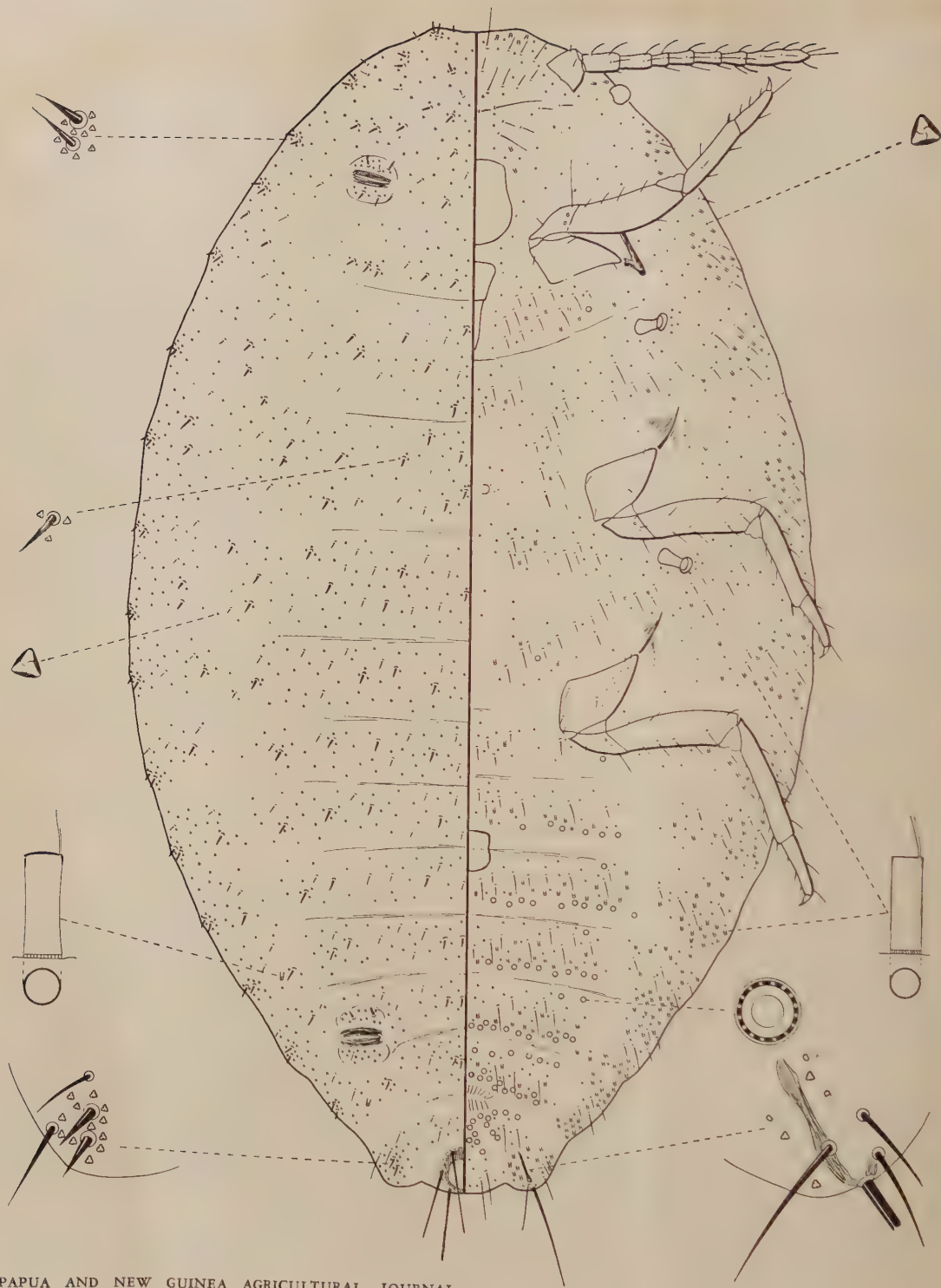
New Guinea: Sepik District, Maprik Sub-district, from the following villages: Apangai, 22. V. 1959; Aunyelum, 19. VI. 1959, associated with *Technomyrmex*; Aupik, 20. VI. 1959; Bunahoj, 22. VI. 1959 (holotype); Gwalip, 19. VI. 1959; Naramgo, 19. VI. 1959; Neligum, 22. VI. 1959; Numakum, 20. VI. 1959; Numango, 22. VI. 1959; Suanimbu, 19. VI. 1959, associated with *Technomyrmex*; Tentegun, 23. VI. 1959; Yanago, 19. VI. 1959. (J. J. H. Szent-Ivany).

It was found to cause severe damage to roots of yams (*Dioscorea* spp.) in storage.

Notes

This species comes very close to *P. dorsospinosus* Ezzat & McConnell described from material intercepted in U.S.A. from China, but differs in a few constant features. The multilocular disc pores are much fewer, lying in single transverse rows except on the eighth segment where they are in a double row, the total being about 125-160. In *P. dorsospinosus* these pores lie in double rows on the four prevulvar segments, the total being about 350-400. Furthermore, in *P. dorsospinosus* each prothoracic group of tubular ducts extends from the margin and around the procoxae to a point near the labium but in *P. dioscoreae* the prothoracic marginal groups are quite distinct from those around the procoxae.

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USE OF HORMONE HERBICIDE FOR KILLING LEUCAENA GLAUCA

P. L. STALLWOOD *

DIESELENE or kerosene solutions of the hormone herbicide 2,4,5-T have proved effective in killing *Leucaena glauca*. The solution when applied directly to the bark causes yellowing of the leaves within a few days. By the end of the fourth week the *Leucaena* is completely defoliated, and the tree dries out completely in a further two to three months.

Dieselene or kerosene alone will also kill *Leucaena*, but these oils are much slower than the hormone solutions. Yellowing of the leaves does not start until the third or fourth week after application, defoliation is complete within six to eight weeks and the tree may take longer than six months to dry out.

Water suspensions of 2,4,5-T failed to kill *Leucaena*.

Method of application

One-quarter per cent. solution of 2,4,5-T in kerosene or dieselene is painted directly on to the bark of the *Leucaena* in a band six to eight inches wide, right around the trunk of the tree, at ground level. If the herbicide is painted higher up, the tree will sucker below the point of application.

A four-inch paint brush is suitable for applying the solution.

The herbicide should preferably be painted directly on to dry bark and not on to very wet bark. However, applications when the bark is slightly damp have proved effective.

The solution will also kill the tree if it is not painted completely around the trunk, but the action is much slower. The tree will take up to six months to dry out.

Method of action

The bark at the point of application blisters and splits, dies and usually lifts away from the trunk. The tree dries out from the top, down to the band of application. The effect is that of ring-barking and the tree remains alive below the herbicide band. If, however, the band extends to the base of the tree there will be no suckering and the tree will die completely.

Experimental Observations

1. One-quarter per cent. solution of 2,4,5-T has been found to be the best. Below one-eighth per cent. or above two and a half per cent. the effectiveness of the treatment is reduced.
2. Kerosene and dieselene are the most suitable diluents. Both are equally effective, but dieselene is preferred because it spreads more evenly over the bark.
3. A mixture of 2,4,5-T and 2,4-D had no advantage over the 2,4,5-T solution. The herbicide 2,4-D had no effect whatsoever, apart from that which could be attributed to the dieselene.
4. Frilling of the bark prior to treatment has shown no distinct advantage over direct bark applications.
5. Weather conditions are unimportant. However, the herbicide should not be applied directly to wet bark. Slight dampness is of no consequence.
6. Unless the herbicide comes into direct contact with cacao trees, it will not harm them.

Use of 2,4,5-T for Shade Thinning

This method of killing can be employed for thinning *Leucaena glauca* shade in cocoa and coffee plantations. The trees so treated can be

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left to decay *in situ* or removed when dead, when the smaller branches have fallen away and the main trunk is brittle and light and thus easily handled.

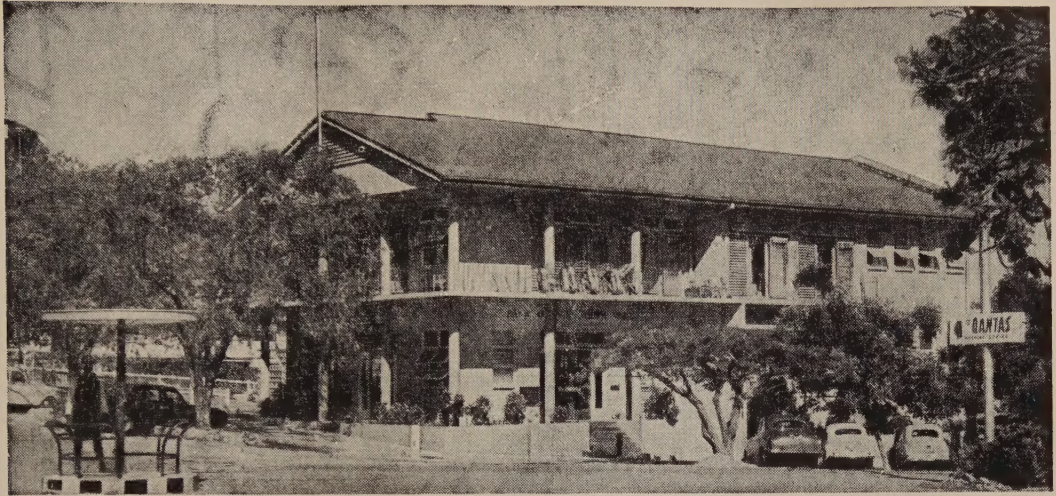
The method is useful where labour is not immediately available for shade thinning, as the shade can be effectively reduced using a small amount of labour, and the cleaning up done later.

Summary

To thin *Leucaena glauca*, paint a one-quarter per cent. solution of 2,4,5-T in dieselene directly onto the bark of the tree, in a band from *ground level* to, six to eight inches above. Maximum effect is obtained by completely encircling the trunk. The application is best made by using a four-inch paint brush on to dry bark, although slightly damp bark is of no consequence.

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